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FOOD TECHNOLOGY

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News of the Institute
Current Abstracts for the Food Technologist

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FOOD TECHNOLOGY

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POLICIES AND PLANS

In this, the second, issue of FOOD TECHNOLOGY, we are able to tell our readers something about the plans and policies under which our new journal will be published.

A new department, "Current Abstracts for the Food Technologist", is instituted in this number. Credit for the excellence of this department goes to Dr. Aksel G. Olsen.

Under "News of the Institute", will be published messages from the President, a record of action taken by the Council, announcements, and Institute news of all types, including that of regional sections. Secretaries of regional sections are asked to send news regularly to Professor Bernard E. Proctor,* who is responsible for the splendid start that this department has made.

The foundation material for FOOD TECHNOLOGY is the papers presented in the annual Food Conferences of the Institute. Additional papers will be published, however. It is FOOD TECHNOLOGY's policy to publish any article which, in the judgment of the editorial board, is suitable for the columns of the journal, whether it was presented at a Food Conference or not.

The right is reserved to either accept or release any paper, including those presented in the annual meetings. This must be the policy at least until it becomes possible for a Reviewing Committee to pass on manuscripts in advance of the meetings in which they are to be presented. We wish also to reserve the right to publish or to release papers that are presented in meetings of regional sections. Secretaries or proper committee chairmen of regional sections are invited to transmit such papers to the editor, remembering that the papers must first be put into form for publishing.

FOOD TECHNOLOGY is behind schedule in publishing the papers presented before the Buffalo Food Conference because of the unavoidable delay attendant upon getting the journal started. We expect to catch up quickly, however, and even hope to begin publishing papers from the Seventh Annual Conference in Boston in the third number, to be issued in July. This will be possible, however, only in case the manuscripts are received by the editor in advance of the meeting. The assistance of the speakers and of the Committee on Programs to make this possible is hereby solicited.

Address of the editor: Owens-Illinois Glass Company, Toledo 1, Ohio.

*Address given on page 1.

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FOOD TECHNOLOGY

VOLUME 1 APRIL, 1947 NUMBER 2

Editorial

The Food Technologist of the Future[1]—Bradley Dewey

Food technology is one of the very oldest and yet one of the very newest, fastest changing and fastest growing activities of our whole social fabric. From earliest times man's primary interests have been food and clothing. But food had to come first. What use was it to be clothed if one couldn't eat? And then in large parts of the world clothing was not important.

Furthermore, emotionally and culturally, food technology was closely tied to religion. The priests of the ancient religions were the great food technologists of their time. They determined what was to be eaten and what was taboo. Without refrigeration to prevent rapid spoilage and without a knowledge of how to inspect for trichinosis or how much cooking was necessary to render it innocuous, they were the ones who had to make the decision that took pork off the tables of many millions, —or should I say out of the fists of many millions. However, perhaps we shouldn't talk about these good old days, for I doubt if today's clergy would make good food technologists, and, from my knowledge of you, I'm quite sure that mighty few of you would make good priests.

Food technology, as we know it today, has grown with the developments of modern transportation, centralized slaughtering and the application of the principles of sanitation, sterilization, refrigeration and packaging. Along with these have been the problems of trying to make our foodstuffs as good as the advertising departments portray them.

These trends demand that food technologists know the principles of biology, not only the biology of the animal kingdom but also that of plant life. They demand that food technologists know the fundamentals of comparative anatomy and of physiological processes, that they be well versed in organic chemistry and bacteriology, that they understand the principles of sanitation and enzymatic actions, that they have a working familiarity with many of the principles of mechanical engineering, of physical chemistry and of the technologies of the food industries. On these foundations, stimulated by work in fields growing lightning fast, we have the food technology of today and a heritage of which every food technologist can be, should be, and is proud.

No one can predict the food habits of the tomorrows. One can't predict the food habits of tomorrow for the citizens of a community like Buffalo. But we do know that the food industry, sparked by science on a rampage, will make tremendous contributions to the wealth, welfare, happiness and health of mankind.

If women continue to spend more time out of the home and to demand that more of the work of the kitchen be done by machines in factories, the food technologist will have to take on more and more of a burden. A few years ago all too many scientists and engineers smiled or made wry remarks when chemurgic chemistry was mentioned. Today they are having to eat their words. Tomorrow they will be eating the works of the chemurgic chemist.

[1] Presented at the banquet of the Sixth Annual Food Conference, Buffalo, N. Y., March 19, 1946.

Editorial

What are the trends going to be? We have seen the Germans start with sawdust and end up with synthetic butters and sugars. Every day sees our diets reinforced with a new vitamin either scoured from nature or synthesized by the organic chemist. Plants are being grown on soils that were considered useless, yes, even without any soil at all. But how long and how far will this trend of breaking apart the diet of our ancestors into little pieces and then reassembling them continue? Some say that if we are to continue to live city lives, it must go further and further. Others say why not eat compressed grass and let nature do the job as she has done in the past,—as she does for animals?

The war showed us some of the wonders wrought by food technologists. They enabled our G.I.'s to eat a healthy, balanced diet in the Arctic, in the Temperate Zones, and in the Tropics. They gave our men clean food regardless of the filth around them. But they didn't solve all of the problems and, if anyone thinks that they did, ask any G.I. how he would like to live for six months on K rations.

The food technologist of the future must mold his work to fit certain criteria:

1. He must recognize the demand for better nutritional values and balances.
2. He must recognize the ever increasing demand for still better sanitation and the inclusion and preservation of every element that helps maintain health and thereby avoid the rising cost of medical care.
3. He must, above all, recognize that with an increasing standard of living and resultant high wages, operations must use a minimum of labor, whether on the farm, in transportation, in preparation, in packaging, or in preservation and marketing.

And in doing these he must recognize that with an ever increasing standard of living the purchaser will constantly demand and obtain better appearing foods, better tasting foods, foods that are easier to prepare and foods that are priced to reflect increased desires for more automobiles, more movies, more radios, more of those things which used to be considered luxuries.

How is all this to be brought about? It can only come about by the application to food technology of a host of the developments of all branches of fundamental science and engineering. The problem of educating the food technologist of the future is a staggering one. Together with the fundamentals that have been taught to him in the past there must come a recognition of the fact that many of the engineering problems of food industries are those of chemical engineers. To solve them intelligently and to be sure that the right concepts are being used, the food technologist of tomorrow must, in addition to all his other basic training, have a sympathetic understanding of and, in many cases, a good working knowledge of, many of the unit operations of chemical engineering. Too much has chemical engineering been built around and associated with the problems of petroleum refining and heavy chemicals. One has but to run through the list of chemical engineering unit operations in a leading text book to realize how many of them are every day problems of food technology. Let me list a few:

Industrial stoichiometry
Fluid films
Flow of fluids
Flow of heat
Crushing and grinding
Filtration
Evaporation
Humidifiers and coolers
Drying
Distillation
Diffusional processes
Absorption and extraction

Editorial

And the table of contents of the textbook I speak of completely omitted reference to the word "refrigeration." Twenty years ago if one were up and coming, one covered the subject of colloid chemistry by taking a course. Look at the field today and then stop and consider that practically every problem of food technology deals with colloidal phenomena, usually several.

A few years ago high vacuum processes were playthings of the physical chemists' laboratories. Now we are asked to look upon them as working tools of the food technologist. Organic chemistry was quite a subject even twenty years ago. Now it has grown so large and so complex that it has many, many fields of specialization, and yet the food technologist is constantly rubbing elbows with all of the complexities of enzymatic action, hormones, vitamins, chemistry of fats, the chemistry of amino acids, the chemistry and physics of odors and a host of other problems. The basic physics of color and its recognition and measurement is new. We can not see what the applications of electronics will be. We know that they will certainly be many and we may even live to see the day when much of the best cooking will be done electronically. The food technologists of the future who are going to determine the boundaries of the growing empires of sterilization by heat, preservation by refrigeration and preservation by dehydration, must have a profound understanding of all that can be done by the scientists and engineering specialists with whom they will have to work to accomplish their means.

What does all this mean? To me it means that the food technologist of the future must be trained in the fundamentals of many sciences and many branches of engineering, and yet these must be taught to him in such a way that he still masters a few, and realizes the power that comes from such a mastery. He must realize that the well trained man can learn other fields after leaving school. He must recognize that just as languages are the tools of common understanding between men, mathematics are the tools of science and enginering. He must recognize that every science goes back to the fundamental principle of formulating the problem, devising experiments, observing results and reasoning from observed results and known facts to accurate objective conclusions. To me it is trite to say that all of this will take five years or six years or eight years. The important thing is that we teach the doctrine that there is a great opportunity in the field of food technology whether for one with a bachelor's, master's, or doctors' degree, providing he or she has a sound training in scientific and engineering methods, a sympathetic understanding of many branches of science and engineering, and a determination to keep on learning.

In closing, I emphasize that it is up to every man interested in food technology to recognize, above all, that there is only one way by which the future can possibly keep pace with the ever changing demands of the field and the ever increasing number of tools at our command. That is by constant study and constant awareness of and interest in a host of other fields. Food technology is a great field for such a man. The mediocre man should stay away from food technology. Modern food technology is in its infancy. It calls for the best men and brains that science and engineering have to offer. Rich rewards are in store for those who will lead modern civilization to better eating, better nutrition and better health.

Editorial

Membership in the I.F.T.

The report of the September, 1946 meeting of the I. F. T. Council, given on page 102 of the January, 1947 number of FOOD TECHNOLOGY, contained a contribution to the perennial discussion on the classification of members in the I. F. T. Let us take the ball and carry it a yard or two—whether in advance or in retreat may not be immediately apparent.

Present Membership Alignment

The Constitution defines four classes of members:

1. The Member, usually referred to as *full* Member, is one who has acquired formal training in college or university sufficient to meet a specified minimum standard, or else, in the absence of all or a portion of such education, has had broad experience extending over a sufficient period of time to give training that is equivalent, in the opinion of the Council, to that required if gained in college study.
2. The associate is one who is officially employed in municipal, state, or federal regulation of the food industries and who does not qualify as a Member.
3. The affiliate is one who is active in some aspect of food technology, or is a scientifically trained person who is looking forward to a career in food technology.
4. The corporate member is a company or a corporation which utilizes the services of personnel in the field of food technology and engages in the production or manufacture of food or in the development of equipment, supplies, or processes for the food industry.

Little Interest In Corporate Membership

The Institute has no corporate members and many Members have expressed the opinion that this category of membership is out of place in a professional society. Logically, this position may be justified, but it is not supported by precedent. Among the societies which have a corresponding type of membership is the American Chemical Society, which gains a considerable revenue thereby, and at the same time renders a real service. Such a membership, of course, is essentially a supporting, or a sustaining, membership. An indication of the shallow interest that has existed in corporate membership in the Institute is found in the fact that the Council has never set a fee for such membership.

The Council's Plan

In September, 1946, the Council accepted, in principle, a policy under which the Institute would have only two general types of membership. One of these would correspond to the present Member classification. Those carrying this classification would constitute the professional group in the Institute. The other would correspond to the present affiliate classification. The present associates apparently would be distributed, some to the first and some to the second type of membership. Corporate membership seemingly would be eliminated.

The Designation, Member

In connection with the first type of membership under the proposed plan, there seems to be only one matter to be settled—that of a name. The present designation, Member, of this classification of membership is not entirely a satisfactory one. Its only mark of distinction from the term, member, applied generally to those affiliated with the Institute, is its capitalized first letter, M. Still less satisfactory would be the term "Food Technologist", because the use of this term would imply a usurpation of rights to it. A food technologist is no less of a food technologist because of his not being a member of the Institute. "Fellow" might do, but ordinarily that designation is reserved as a mark of one who is credited with

some special achievement. Appropriately, a Fellow would be in a category just above that which we are discussing. More about this later.

What Should Be the Requirements?

All agree that members of this classification must form the foundation of the Institute and, while discussions will continue on what the eligibility requirements should be, we shall probably finish our consideration of the question with substantially the same standard of qualifications as we now have. Those who wish to change the requirements will probably be satisfied only by an increase of explicitness in the specifications for Member, and our opinion, gained from experience on the Committee on Constitution, is that it will be very difficult to obtain agreement within the Institute Council and membership on such a change. Furthermore, even though such agreement were possible, we doubt that anything would be gained through such a change.

To stimulate thinking on this point, we urge all I. F. T. members to read attentively Mr. Bradley Dewey's address, delivered at the banquet of the Sixth Annual Food Conference. It is published as an editorial in this number. The last two paragraphs, especially, merit repeated reading and, to emphasize the point that we have just made, we are going to quote a short passage from Mr. Dewey's remarks, which follow a discussion of what should be required training of a food technologist.

"* * * To me it is trite to say that all of this will take five years or six years or eight years. The important point is that we teach the doctrine that there is a great opportunity in the field of food technology whether for one with a bachelor's, master's or doctor's degree, providing he or she has a sound training in scientific and engineering methods, a sympathetic understanding of many branches of science and engineering, and a determination to keep on learning."

We would seem to be well advised not to spend a great amount of time trying to incorporate explicit details into the qualifications specifications for Member, but to be content to abide by the interpretation of somewhat general specifications by the Committee on Membership Qualifications and by the Council. It is necessary, of course, that these specifications, although not too specific in form, do set a high professional standard.

One needs only to have an active interest in food technology to become an affiliate of the Institute. Might it be that this eligibility requirement has, in some measure, been responsible for the low ebb of interest we have seen in corporate memberships? There may be corporations having no trained food technologists, which would desire corporate memberships if it were not so easy for a member of the firm to become an affiliate of the Institute. Would it not be possible for the Institute to fulfill its destiny if the requirements for affiliate were raised, or the affiliate classification were eliminated, and dependence were placed upon corporate, or sustaining, memberships to make the advantages of affiliation with the Institute available to those in the present affiliate class?

Alternate Proposal Is Offered

Before long, the Institute will need a student membership classification to take care of the increasing number of students in courses in food technology. Would we not be wise to consider a membership alignment which includes Fellow, Member, Student Affiliate, and Corporate Member; with Member as the foundation category and with the Fellow and the Corporate Member filling places as suggested earlier?

There are now 30 associates in the Institute out of a total membership of 2238. We are justified in weighing carefully the question of whether or not

an associate who is not eligible for affiliation with the I. F. T. on the basis of qualifications suggested for one of the four classifications named above is entitled to affiliation. Government employees, of course could not become associated with the activities of the Institute through a corporate membership. Would it be out of order, however, to extend the qualification specifications for the student affiliate to include those government workers who are interested in food technology but are not eligible to be Members?

Expressions From Members Are Desired

This editorial is written primarily to stimulate thinking. If it does that and results in bringing many expressions of opinion to the Council and to the Committee on Constitution, it will have served its purpose well. The names of the Councilors are given on page 2. The Chairman of the Committee on Constitution is Dr. M. A. Joslyn, Department of Food Technology, University of California, Berkeley, California.

How to Join the Institute of Food Technologists

A second purpose of this editorial is to tell anyone who is interested how he or she may become affiliated with the Institute of Food Technologists. Remember, first, that, notwithstanding all of the discussion that is taking place, the membership categories are still these four: Member, associate, affiliate, and corporate member. The procedure for joining the I. F. T. is as follows:

1. Fill out an application blank.

   If the applicant resides within the area covered by a regional section, the application form should be obtained by writing to the Secretary of the section. These are listed, with addresses under "News of the Institute" in this number. If the applicant resides far from the headquarters of a regional section, the application form should be obtained by writing to the Secretary of the Institute.

   The application blank calls for information regarding the training of the applicant in the field of food technology. Since the question of qualifications is important, it is necessary to obtain the endorsement of three Members. If the applicant is not acquainted with three persons whom he knows to be Members of the Institute, he should ask the person to whom he writes for the application blank to give him the names of several Members in his locality, to whom he might become known.

2. Send the completed application to the office from which the blank was received.

   If the application is submitted to the Secretary of a regional section, it is first referred to the section Committee on Membership Qualifications and then sent with the recommendations of that committee to the Secretary of the Institute. The Secretary submits the application promptly to the Institute Committee on Membership Qualifications, which makes a recommendation to the Council as to the type of membership to which the applicant is entitled on the basis of his qualifications. The Secretary secures action by the Council and reports the results to the applicant and to the Secretary of the regional section.

   If the application is submitted by the applicant directly to the Secretary of the Institute, the procedure is as described above, following the receipt of the application by the Secretary. In such case, however, if the applicant resides within the area covered by a regional section, the first step of the Secretary upon receipt of the application, usually is to request a recommendation from the Committee on Membership Qualifications of the section.

Membership Drive

President Harvey and Chairman Harry E. Goresline of the Committee on Membership are planning a drive for new members this spring. Help the Institute by joining in this drive.

C. O. B.

Editorial

Food Research Is Defense Work, Too

It could have escaped our attention, but, up to this time, we have seen no indication of an intention on the part of those who will decide where the cuts in the Federal budget will be made to apply the ax to food research activities. Even should this observation accurately depict the situation as of today, complacency on the part of I. F. T. members in respect to the likelihood of reduction in funds for Federal agencies to use in food research is not warranted. The job of wielding the ax comes late, after the budget goal has been established, and the chances are that, even when this appears in print, the job will not have been completed.

We should watch attentively for any move that might mean that food research will suffer because of a cut in the budget and we should be ready to help our Senators and Representatives to realize that food research is defense activity—perhaps in greater degree even than research on destructive weapons, and certainly greater than some other activities that are presented to us as necessary defense activities. It could even be as important as giving aid to Greece and Turkey.

It might not be amiss to point out that research during the past quarter century in the food field provided the foundation for a World War II development of one of the most spectacular of destructive weapons, biological poison. It is not such a development, however, that gives food technologists the greatest sense of pride in their work. Their greatest satisfaction arises from their contributions to the general health and welfare of mankind.

No thoughtful person could have passed through the last war without realizing that victory at arms is achieved by the belligerent which has resources to back up its armies. Are we wrong in saying that the most important of these resources is food, by means of which is maintained the health of both the military and the civilian populations?

In times of no military combat between nations, food resources are of even greater importance, proportionately, than in war-time. The facts in this regard may not be so easily recognized in times of military peace as in war-time, but the question of how well the peoples of the nations are nourished is of vast fundamental importance as a factor in setting the date for the next holocaust, if, God forbid, such there is to be. We mean to say that proper distribution and use of nourishing food can be a powerful factor in preventing another war. This assertion is based upon the sober reality that wars have their inception in diseased minds, while sound bodies generally shelter healthy minds. Healthy minds, subjected to proper training, are the best antidote for jingoism. Through the offices of the World Food Council, our research may help other nations to produce the food they need.

Let us see that the progress of food research does not suffer at the hands of our legislators through neglect on our part to do what we can to preserve it.

C. O. B.

LINE OPERATION DESIGN IN THE FOOD INDUSTRY[1]

JOHN I. THOMPSON
John I. Thompson and Co., Washington, D. C.

When Dr. Proctor asked me to take a spot on this program, he resorted to that old sales dodge of offering me one of two subjects. The result was that instead of choosing between talking and not talking I found myself choosing between them, and took what I thought was the easier as a way out of my dilemma. There is a moral in this: Just don't give the sucker a break. And I want to use it here in contrast: Too often we adopt the same strategy in development, in making a change. We force the change, or the way of making it, saying either "this or that" must be done, and letting someone less fitted technically than ourselves decide between these. This sells "something" to be done. But wouldn't it be better to know what is the best thing to do, and the best way to do it? I think, sometimes, that more poor engineering results from use of questionable selling methods by the engineer than from lack of his technical ability. There is never any need to "sell" the qualifications of the scientist preparing that result.

Incidentally, there are so many of these cases of special pleading—in fact, I just read one, a very extensive article on palletizing, but it assumed that palletizing was the thing to do and merely offered different methods of palletizing. Its first section was properly titled: "Surveying the Materials Handling Problem." But instead of the "materials handling" problem, it was a survey of the preliminary design factors for palletized handling. It was very misleading. Maybe pallets do not fit your case. Its author would have to "sell" me on their qualifications to study a "materials handling" problem. They are, apparently, experienced, but with pallets only. The engineer with a proper scientific approach might use this experience, but only after first determining that palletizing was the proper application.

In the first place, what is meant by "line operation"? There can be several definitions. They can be narrow, defining only one type, as "continuous." Or they can be broad. I consider a line operation as one where the series of steps in producing a definite quantity of product in a given time are in balanced relationship with each other successively; as to location of each step, as to relative volumes in process for each step, and as to dependence of preformance for any step on that preceding it.

Thus, six batch kettles performing a cooking operation, these feeding a single conveyor-cooling operation, which in turn produces a split slab, hand-sized, each half going to a packaging unit, and the production of the two packaging units passing through a case sealer with definite accumulation ahead of this case sealer because it also serves several other packaging centers, and finally, with the cased product going by conveyor to a warehouse, form a line operation. And it would still be a line operation if the conveyor-cooler were replaced with tables in proper number. Or, if the kettles were replaced with a continuous cooker.

It is not a line operation, however, when unit operations are performed in bulk, "out-of-face," independent of succeeding or preceding ones. It is not a line operation when one person makes and finishes a single unit of a repetitive product at a bench, then makes and finishes another. It is not a line operation when, for instance, containers are filled all one day, and maybe two or more, and then rehandled for

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 18, 1946.

labelling; or when vegetables are peeled into bulk containers at one point for distribution to dicers at another, for dicing into bulk containers there and subsequent redistribution. The housewife making a single pie can set up her unit operations to simulate a line operation. But the pie manufacturer cannot have each baker follow this and have line operation because of repetitive units, because of unbalance of time required for each unit operation at the baker's work place, and because of the added operations of packaging, bulk raw material handling and the like. To be done in line operation, the processes of making a product must have the quotient of volume divided by time, the rate, in other words, equivalent in each step or unit operation.

My approach to any design problem is along a definite line. We use a guide, checking off each step. This chart is a generalization of the steps we take—the "why," the "what," and the "how."

First, we have the preliminary study. Here we determine the product requirements, its design, sales, etc.

Second, we have those questions to be answered to justify the job, labor-wise, material-wise, and quality-improvement-wise. Also, if increased production is the mission.

These two steps determine whether or not the design should proceed—and in what direction.

Third, comes the design study. The listing of unit operations, the volume-time relationships for each, the standards requirements.

Fourth, we make the estimates, determine the operating details, by carefully following the steps we have found necessary to consider.

Fifth, is our design and its application. Here we have established a series of steps through which we pass in getting a satisfactory design and specification. The details of controls needed and all the controls needed; the details of how it all goes together; the design for building the line.

Sixth, we have those steps common to all installations, and those required subsequent to installation to obtain satisfactory operation.

I might add that the solving of any of these problems is best done following a definite order of investigation and plan. Within that, it is best to take a leaf from Plato and analyze it by going backwards from your object. I mean, for instance, starting with your finished package in a warehouse. Then, consider the following questions:

How do you want to get it there?
How do you want it finished?
How do you want it filled?
How do you want the contents at the conclusion of making?
How do you want raw materials to arrive?

In this way you avoid having to follow a less desirable way of going through one step—of adding an unnecessary step or operation or gadget—because of the way you worked out the preceding one. After all, the ultimate product is all that is wanted. So start with that and work back.

I feel that all the foregoing must be followed in order to obtain an operation which can be assuredly successful. This is engineering. Do not play "hunches." Design not based on careful planning so frequently misses the boat. Do not sacrifice a good plan just to employ a clever mechanism—a brilliant invention of a machine.

We must be sure of quality. Just because we have found a time-temperature relationship for cooking in a kettle gives us certain results, we cannot say that the same BTU output in a surface on which the product in preparation may pass will give us like results. Or, a continuous flow of pieces, mechanically handled into

wrapping, may be possible but not satisfactory when the pieces are irregular, or when it is impossible to inspect them and they need inspection for maintenance of a quality standard.

And in cost, continuous processes may be prohibitively expensive under certain conditions. Generally these conditions are when:

(a) Volume of production is too small.

(b) Use of equipment is intermittent due to seasonal or other production and sales reasons, and the total occupation is only a small fraction of a year.

(c) Time-in-process is great for technical reasons, hence making "travel" of product through any step an excessive distance, thus, perhaps, necessitating extensive building occupancy, etc.

An analysis following the lines of the check-off list will result in determination of the cost comparisons enabling justification of a continuous process on a return-on-investment basis.

There is one feature in most continuous processes that I want to emphasize. That is, generally a continuous process results in a more consistent quality standard. The controls necessary to operate satisfactorily inherently give uniformity to product.

Automatic controls make the continuous process possible. They are most important to design right. What I call automatic controls fall in these categories:

Non-manual means of directing
Non-manual means of influencing
Non-manual means of recording

The first are those requiring compliance. They obtain predetermined rates. They are positive controls. They are the directive controls. The second are those implying persuasion. They modify or affect a flow, a movement, a rate, and the like, influencing it toward controllable limits. They are the controls that straighten or retard a package so that it can be readily registered for the next operation upon it. The last, recording, is historical. But in many cases, a most necessary function. It is the recording of any happening from which we learn to govern such happenings in the future. It is the recorded variant that tells us to suspect that lot before its release, or may tell us how to apply the next, or a subsequent process. All these have their places when your line operation finally becomes "continuous."

I would like to say a few words about the details application. It is important to control the right thing at the right place. For the first category, the directing controls, this is especially true. Pick a point part way in the process step which always bears a definite relationship with the end point. Control from that. For instance, in a heat exchanger—say, an open gravity plate cooker—you might control the amount of cook from the product as it comes off and depend on the intermixing inherent in the receiving element to get uniformity. But it is better, even if needed to be done with a thermocouple, to take a point midway on the plate, knowing that a condition at that point will mean the condition you want at the end. To arrive at these points almost always means experimentation. But it is worth it.

Another thing, automatic controls imply a closed loop of action and counter action, operating without human aid. See that they comply. An indicator is not a controller, and so many times a continuous process is installed and to save installation cost, some indicators are applied for human attention and action. Then troubles begin, for, in a continuous process, the material in process is always on the move, and a man is not always moving.

Where possible, avoid controlling by influencing rate of product being processed. This can give you some weird results. Instead, direct the conditions required to

process the product. This keeps your overall control more nearly positive and does not require provision beyond for the varying flow otherwise obtaining.

Do not forget your recorders. Use them. But do not let them unduly influence you. I recall studying a plant not too long ago and being shown a set of perfect recorder charts extending over many months. Yet there were plenty of troubles. I was lulled into a sense of wellbeing concerning the phase of the operation covered by these charts. Finally, not being able to find the trouble elsewhere, I planned to put checking instruments in. When I suggested that, the client's chief engineer confessed. He had all the instruments rigged so that the charts were perfect. His excuse was that the original installation was designed to do certain things—and did them to his satisfaction, so why upset everybody by having these instruments say otherwise. That is the difficulty. Most standards are somewhat arbitrary. The state of a product in a single unit operation may not be appreciably affected by variations within that operation, but for the system of steps, its effect on subsequent operations, the closer tolerances may well be necessary. It is desirable to keep that in mind—the tolerances at one point are those that in conjunction with the tolerances at all points will give the result desired. For instance, the amount of water evaporated at one stage may be a greater or lesser quantity. But it cannot be both if the next stage depends on either.

Now, let us discuss getting the greatest advantage from batch unit operations by applying line operation principles to them. Always determine the unit for an operation by keeping it in balance with the productive rates of previous or succeeding ones. Do not use some greatly oversized unit, just because it is available. Make sure that, although it may be usable, it is not going to promote problems of temporary storage, handling, quality control. Then arrange the steps to eliminate as much transfer handling as possible.

In designing, it is necessary to pay a lot of attention to accumulators. Much can be gained, for instance, in dumping a batch from a processing unit at one stage very rapidly into a container from which it may flow or be moved at the required gradual rate, releasing the processing unit for the next batch. Accumulation provision at the proper places will be the difference between satisfactory or unsatisfactory operation. A good example of this is found in moving materials. Generally, if it is required to move a lot of cases from one point to another, the largest number that can be moved in one load results in the most economical handling. If, however, the flow of cases at the initial point is continuous, and the take-away at the end point intermittent, a continuous conveyor line, if providing accumulation by adequate gravity sections or other means, may be even more economical. In other words, it does something else while conveying; it achieves the sort of thing we always look for; a combination of steps as a single operation, that of temporary storage and that of conveying in this instance.

In the design of a line operation in the food industry there are many possible applications of successful units used in other industries. There are, however, certain points peculiar to the food industry that must be considered in such applications, or in any design, for that matter. These "tremendous trifles" greatly affect the practicability of the installation. Considered, a great deal is gained, since the other industries' machines have solved the operation. A wholly new machine need not be designed.

Those things affecting inspection must be considered first. Much of the inspection in the food industry is organoleptic. A closed system, satisfactory for a ceramic slip, may not be usable directly for a food product. Due to the need for perfection, when it is redesigned, space and time allowance must be provided to allow

for basic human reaction elements; the average reaction to sight, to touch, to sound, the fact that the included angle of sight from the eye is but 1½°; the need to see all the product. We have, of course, bean inspection machines using in place of human eyes, phototubes; in place of a brain, a cathode tube. But we have many operations of a magnitude not justifying such developments.

The design must start from the point of observation and selection best suited for the inspector. Then the machine adapted to that point, with each compromise carefully judged in its effect on proper inspection. A good illustration is in the conveyor inspection of tomatoes and the like. Use of rollers as the belt, which by rotating, rotate the tomato, will make a tremendous difference.

Another point is that of cleaning. Many devices permitting a line flow of operations in, say, heavy chemicals, or inert substances, can be used to attain smoother operations in the food industry. But some redesign is necessary. For instance, the plastics industry has a continuous mixer which intimately disperses even the smallest amount of color, etc., in heavy masses. These masses are of a nature frequently encountered in foods, but only of greater specific gravity. This unit can be used in principle—but in principle only—for, as constructed for its original purpose, it will not allow for cleaning easily, nor for an eye to scan its entire surface that comes in contact with product.

Many bulk or mass conveyors likewise can be used for food by substitution of quick-opening cleanouts, etc.

Where another industry uses a handhole in a piece of equipment, we may have to resort to swinging a whole side open—using properly designed hinges.

Where another industry fabricates by assembly of fitted sections, we may have to cast a whole, or integrally weld, because of crevices, however small.

Lubrication may prevent the use without redesign. Perhaps we have not studied this enough. Perhaps we can take some wear, if we cannot effect redesign. An apparently sloppy fit can be good engineering if it accomplishes the function and is justified by cost comparison.

And, of course, we have to consider the right materials, rounded corners, the use of detergents, drainage points, and the like.

We also have those things affecting worker comfort—making the job easier. Where a machine works on, say, a cold process in another industry, and requires attention of operatives in its vicinity, it may be adapted to a food process of great heat or other inherent condition not conducive to good working conditions. Then the work place must be carefully considered. Also, we have wet occupancy of areas where a safe and otherwise satisfactory working condition may be upset by the blocking of space with a machine. These considerations are only a few. Unless imaginatively considered, success in installing a line may not be attained.

Another point I want to touch upon is this: When a line operation is effected, with its obvious savings evident, every worker on it must have an obviously easier job. Let me illustrate. We considered a peanut room recently. There were two men employed in it. Several women were used part time. Little or no rearrangement, just incentive—or putting a man on the job to perform all the operations—would have resulted in making one man do all the work of processing 1500 lbs. of peanuts per hour in several ways. We studied the job, however, saying that if we took the other man out of the room, and the women, the remaining job had to be an easier one than either man had before. The result was the rearrangement to accomplish this, plus a much greater capacity, yet using only one man who had little to do manually and plenty of time to take care of his controls.

When assigned a task of working out a line operation, there are several things that may be done which will prove helpful in the approach. One of the first is to just count the number of times an ingredient is picked up and is put down. For instance, we had a peanut operation to study—guess I like peanuts—so we first followed one peanut, so to speak, from the time it entered the plant until it left as part of a finished product. It actually was picked up and put down by hand 67 times! By examining these successively, we bunched groups of them to find those places where effort directed would result in the most return.

I refer to a particular case. The product in this instance had one raw material that required refinement. Then it had a blending requirement, followed by a drying one. Then came filling into containers, casing containers, holding the cases for shipment. There were three sizes of containers for customers to use.

The process originally was one of operating the refining units as a separate plant. Raw materials came in. Were dissolved. Impurities precipitated in batches convenient to the equipment. Pan drying was resorted to and the material held for the transfer to the blending building. Lack of continuity caused a considerable space provision for this storage, and for bulk transfer. Where the blending took place was provision for bulk drying in trays. All over the place. Then transfer to sifting. And again to filling operation hoppers. Packaging was a disjointed affair with holding ahead of labelling and casing, and transfer to stock. Age of finished product was a technological problem due to lack of keeping facilities. An outgoing quality at a constant level was desired, but shipments to the trade were not constant. All in all, 44 men and 38 women workers were used for a certain annual production level.

This entire manufacture was then converted to a line operation. A satisfactory one day's production of finished goods was arrived at, and from that conveying of cases, with accumulation, case packing and sealing, and diversion to stock or rail car or truck was worked out. Then packaging equipment, keyed to casing rates. Then a new manufacturing process—another type of refining and drying—all units being properly sized to supply each following one and take from each preceding one, with just the right amount of accumulation for safety in between. And there were 9 women and 5 men, and two mechanics, doing all and more than before.

I give this as an illustration of an extreme case. Its represented savings, including maintenance, etc., are a good return on $1,000,000. The installation cost was far, far below that. In addition, the product could be made to standard at will and repetitively the same. Yields were improved.

When you feel you want to replace a job operation with a line operation, let your imagination go—but keep your imaginings to paper until you have followed each step through and justified it. What may look good at one point in the manufacturing of a product may cause you to lose that advantage ahead of or behind that point. Just never improve a single unit operation without tracing its effect on others in the same process.

WHAT DETERMINES QUALITY IN FOODS?[1]

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Quality is something about which everybody talks but about which very little is done. It is a word that connotes the finest attainable, a word that the honest food processor reveres and one behind which the unscrupulous hides. Quality means many things to many people. The reason is that many people have used the word in so many different ways. In fact, the word has many different meanings. Quality means a distinguishing property, characteristic or attribute, a distinctive trait, peculiar power, capacity or virtue. Thus quality may be used in connection with not only food but in connection with people, goods, music and the like—in fact almost anything.

Suffice it to say that quality is a very comprehensive word and therefore meaningless as commonly used by many food processors. This paper will confine itself wholly to what determines quality in foods. For this purpose we shall go back to the origin of the word quality in Latin, *qualitas* which means literally "how constituted." In foods this, you will agree, is most essential. We have emphasized sanitation and cleanliness to the point where many have come to believe that quality and sanitation are synonymous. As a bacteriologist and sanitarian no one appreciates more than I the importance of cleanliness and sanitation in the food industry. They are absolutely essential in the production of any high quality food but they are not the only essentials. It is becoming increasingly evident that we should know not only the sanitary history but also the chemical composition and the genetic status of a food. Other things which we must know to determine quality in foods are the kind of soil upon which they were grown, when and how harvested, the length of time between harvesting and processing, how they were processed, the length of time and how they will be stored before using and finally how the housewife or chef will cook and treat the food after it has been purchased—all are important in determining quality in foods. The treatment which the food receives in the home is most important because no matter how scientifically and carefully the food has been produced and handled up to this point, a great deal of the quality which has been built into it and conserved during its manufacture can be lost by improper handling and cooking in the home.

NECESSARY ELEMENTS FOR QUALITY

Genetic composition is one of the first essentials of quality. Every one knows that there is a very great difference among the different varieties of food, even of the same species, as regards flavor, color and texture. It has been necessary to develop new varieties of certain foods for freezing as distinct from canning. There is no question that one of the answers to better dehydrated foods will be the selection and breeding of new varieties more suitable for dehydration.

One of the newer ideas is to breed plants for chemical composition just as they are now breeding them for productivity and disease resistance. Research has shown, for example, that some varieties of tomatoes have twice as much vitamin C as others. A Northern Spy apple contains five times as much vitamin C as a McIntosh. More recently a variety of apple, Calville Blanc, has been discovered at Geneva, N. Y., which contains several times more vitamin C than most varieties of common apples.

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 18, 1946.

Of the 94 lots of apples tested, only 8 had vitamin C values above 15 milligrams per 100 grams of apple. The Calville Blanc contained 37 milligrams per 100 grams of fruit, which, as you know, compares very favorably with the vitamin C content of oranges, grapefruit and tomato juice. We have long been familiar with the high fat content of the Jersey and Guernsey milk as compared to that of the Holstein-Friesian breed of cattle. Two new rust-resistant wheats, Renown and Regent, contain 25 percent more vitamin B_1 than Marquis, for years the standard wheat of the west. These are only indications of future trends in this direction. By genetics the protein content of corn can be varied from 6 to 16 percent. In breeding hybrid corn the emphasis has been placed on quantity rather than quality, whereas both could be obtained by intelligent selection.

INFLUENCE OF SOIL ON FOODS

The second factor which determines quality in foods is the soil upon which they are grown. It has long been recognized that the best race horses are those born and bred in certain regions of Kentucky. This was taken for granted and frequently treated as a joke for many years. However, research has shown that in the chernozem soils we may find deficiencies in potash and phosphorus where the parent materials are low in these elements. In the rolling and hilly sections of such states, erosion removes the acid and leached materials as rapidly as they are formed, leaving the soil young and relatively immature and calcareous soils lie within the reach of plant roots. Many of the soils are formed from parent materials high in phosphorus. The net result is blue grass, containing abundant bone-forming materials, which produces an excellent type of race horse in these localities. Another example is the protein content of wheat which increases from east to west across Kansas depending upon the thickness and nearness to the surface of the underlying layers of limestone.

Research has shown that not only health but the lack of health—disease—can and does come from plants grown on soils deficient in certain chemical nutrient requirements. The list is long and since this paper is not dealing with nutritional diseases we shall but mention them. The nutritional value of such inorganic elements as calcium, phosphorus, iodine, copper and iron has been demonstrated by many investigators. Their presence in a human diet is absolutely essential to health. Their lack causes disturbances known as nutritional diseases such as bone maladies, anemia, goiter and other diseases. Other inorganic elements which should be mentioned are cobalt, nickel, manganese, magnesium, fluorine, bromine, zinc and sodium, all of which play a minor, although, important part in the physiology of the body. On the other hand an excess of certain inorganic minerals causes trouble, the best known examples of which are selenium or "alkali disease" in cattle and mottled teeth caused by excess fluorine in food and water.

MATURITY OF FOOD

The age or time at which a food, especially a vegetable or fruit, is harvested determines to a certain extent its quality. From the beginning of life to maturity very fundamental biochemical changes take place. Foods in general have been harvested at or near maturity with no thought of harvesting them when they are nutritionally mature, *i.e.*, have the maximum nutrition value. Foods like individuals pass through a cycle: birth, youth, maturity, old age and death. Many of the green vegetables such as peas, corn, snap beans and the like are harvested in their youth. Fruits, as a rule, are harvested in their maturity. Meats, in general, are harvested in their youth or at a tender age.

Grapes when green have about equal quantities of tartaric and malic acids present. At maturity the latter acid has disappeared and during fermentation practically all the tartaric acid is precipitated. Little or no sugar is present in the green grape, mostly starch, but at maturity the starch has been converted to sugar. In experiments with young spinach, the phosphorus content increased for about the first 30 days after which it rapidly decreased until it was less at 48 days than it had been at the end of 10 days. Chemical changes are taking place constantly in food during growth and we must know when to pick each particular food in order to have the highest quality.

HARVESTING THE FOOD

"Garden fresh" is a trite expression but conveys a wealth of meaning. After the food is harvested chemical action doesn't cease but, if anything, is accelerated. While the food was still living it was being nurtured by the mother plant or living mechanism so it was being built up in most instances. However, as soon as it was severed from this living source there began deterioration processes and the longer they continue the lower will be the quality of the food, in the case of many vegetables. In most fruits the process is slower, and in meats these digestive processes enhance its quality up to a certain point. There is such a variation in the harvest time of different foods that it is not possible to lay down hard and fast rules. Suffice it to say that there is a proper time in the life history of every food when it is at its finest, when its quality is best. This is when it should be harvested. There are new tests for peas, lima beans and corn to tell when this is. There are physical and chemical tests for determining the proper harvesting time for other foods. Doubtless similar tests for additional foods will be devised.

HOW MICROORGANISMS AFFECT QUALITY

Extrinsic as well as intrinsic factors are constantly at work to deteriorate food. Most food is grown in an environment of microorganisms. During life, the living tissues have certain protective mechanisms which generally successfully withstand the invasions of these small plants. However, at harvest they swarm over and invade the tissues and ultimately devour them. During this process, flavor, texture, and color suffer and even the food itself may disappear. At any rate, the quality disappears in direct proportion to the decomposition of the food in most cases. The longer the food remains in this environment the greater the loss of quality.

Conditions which favor intrinsic factors such as enzymes and chemical reactions and extrinsic ones such as microorganisms are temperature and moisture. For this reason, certain raw foods are refrigerated at once or as soon as feasible. For a great many years we have recognized cooling and refrigeration in the production of high quality meat and fish. More recently, the hydrocooling of vegetables in the field has shown that bacteria, viner juice, dust and other contaminants are reduced as well as enzymatic activity so that a vegetable more nearly like the one which left the field is delivered to the factory.

SANITATION AND QUALITY

One of the best mottoes for any food industry to adopt would be "Sanitation pays good dividends." It pays good dividends in money and in quality. As just mentioned microorganisms such as molds, yeasts and bacteria start decomposing food as soon as life ceases. Therefore, it becomes self evident that the fewer microorganisms there are present the less decomposition and in general the better the quality of the food. Sanitation is not limited to microorganisms alone but is an all inclusive term as used

these days. Sanitary comes from the Latin, *sanitarius*, which means promoting health. Sanitation in its broadest sense means the establishment of environmental conditions favorable to health. What are the conditions favorable to health in a food factory? They are abundant light, fresh air or ventilation, efficient drainage, plumbing, gutters, traps, etc.; a clean, ample, palatable water supply adequately distributed; clean dry floors, walls, ceilings, partitions, posts, doors and other structures made and constructed of such materials so that they can be readily cleaned; freedom from flies, insects, rats, mice and other vermin; freedom from obnoxious odors, proper waste disposal, adequate modern sanitary facilities for employees such as dressing and toilet rooms, urinals, lavatory facilities including hot and cold running water, soap and towels, properly located facilities for washing, cleaning and sanitizing utensils and hands, and finally properly dressed workers with clean clothes and proper protection of hair.

If time permitted, I would like to discuss the sanitary implication of each of these items and its relation to quality in food because such a relationship does exist. However, I can only briefly mention one fundamental change which has taken place in many food factories such as the dairy manufacturing plants and others. This change is in the amount of water used. The old idea was to use water abundantly. Consequently the floors and walls were wet most of the time. The new idea is to use less water but to use it more intelligently. For example, machines are disassembled and the parts placed on a movable rack and taken to a central washroom for cleaning. The floors and walls are kept dry as much as possible instead of being constantly wet. Microorganisms can not multiply on dry surfaces so that it is really more sanitary to use less water if it is done intelligently.

PROCESSING AND STORAGE

Nowhere along the line does quality suffer more than in processing. There is no known method of processing that does not take something away from quality. This is evidenced by the fact that no processed food tastes the same as fresh food. To date we have four fundamental methods of preserving food, *viz.*, canning, freezing, dehydrating and salting. In each method the processes are the same up to a certain point. For example, in the case of vegetables, no matter what method of preserving is used, they must be blanched which takes something from the quality. After this the processes differ in physical means only. In canning heat is added, in freezing it is taken away, in dehydration moisture is reduced physically, in salting moisture is reduced physio-chemically. The merits of the different methods of preservation will not be discussed. Suffice it to say that the method which produces the highest quality food is the one that affects the original natural state of the food the least.

After processing there is always the necessary storage period until the food is used. It is now generally agreed that the higher the storage temperature and the longer the storage period the greater the loss in quality. In general, there is a decrease in all the vitamins at temperatures above 100° F. which is more pronounced for some vitamins than for others. For canned, dehydrated and salted foods, storage temperatures between 40 and 60° F. are satisfactory for a reasonable period.

The ideal preserving method would be one that would retain all the natural goodness of the food while destroying or inhibiting all the deteriorative agents such as enzymes, microorganisms, and chemical changes. This indeed would be ideal and then all food would be "garden fresh" and of the highest quality. However, imperfect as some of the preserving methods may be, frequently quality suffers most at the hands of the cook.

QUALITY LOST IN COOKING

There is no question in my mind but that quality suffers most at the hands of the cook. Frequently all the quality that has been built into a product genetically, chemically, by proper harvesting and processing, by sanitation and storage is poured down the drain or otherwise ruined by ignorant and improper cooking. Frozen foods can be ruined by improper thawing and cooking. Dehydrated foods are fine when properly cooked. The Quartermaster Corps found it necessary to train cooks in the proper method of cooking dehydrated foods. Canned foods are good or bad according to the cook. Eternal vigilance is the price of most commodities. Take safety for example; it is a commodity and the price is eternal vigilance. If you go on a ten thousand mile automobile trip, from the time you leave home until you return, it is necessary to observe all the traffic and safety rules—not only is it necessary for you to observe them but it is also necessary for every other driver on the road to observe them if you are to return safely. You can make this long trip safely and yet get injured or killed by ignoring just one safety rule when you turn off the street into your own home garage.

The ice cream industry has spent millions of dollars in building factories, machinery and equipment to produce a high quality product. However, it took years to appreciate that much of the sanitary quality was being lost by the unsanitary way in which ice cream was being served by the retailer. They have since corrected this by establishing schools to train people in the proper way to serve their product.

So it is in the food industry. The food technologist must watch each and every step through which the food passes from the seed to the mouth of the consumer. It is not enough simply to produce high quality food. You must do more. You must see that it is properly cooked and served to the ultimate consumer. For in the last analysis he is the beneficiary and the final judge of the quality in any food.

SOME UNSOLVED ARMY NUTRITION PROBLEMS[1]

GEORGE H. BERRYMAN

From ASF, Medical Nutrition Laboratory, Chicago, Illinois, an Installation Under the Jurisdiction of the Surgeon General, U. S. Army

The effectiveness of any nation or of any army is closely related to its state of health. Health, in its turn, is endangered in the absence of proper food, and when lost or impaired, cannot be fully regained without proper nutrition. It is quite apparent, therefore, why the Army has seen fit to establish a vigorous program of research designed to promote the best physical condition possible in its soldiers, insofar as food and nutrition are concerned.

The program for this conference has been concerned with various technologic aspects of food production. Colonel Rohland A. Isker (formerly Commanding Officer) and Colonel Charles S. Lawrence (presently Commanding Officer) of the QMC Subsistence Research and Development Laboratory at Chicago, have described some of the many problems and accomplishments in those aspects of proper military feeding which are perhaps the most directly associated with the interests of the Institute of Food Technologists. It now becomes my pleasure and privilege to discuss some of the considerations involved in the ultimate aspects of your work and interests—namely, the relation of nutrition to health, and some of the associated unsolved problems.

Army nutrition may be looked upon by analogy as a chain of events made up of six links, each link being related to and dependent upon the others. As background for a discussion of nutritional problems still to be solved, let us examine these links. First, in order to have a well integrated food policy that is sound from the standpoint of science, and also economics — national as well as international — the Army must know what the nutritional requirements of the soldier are for different sets of circumstances. The Nutrition Division of the Medical Department has therefore established a medical basis for proper feeding by directing that certain quantities of nutrients should be provided whenever feasible. These military recommended daily allowances are based upon the recommended daily allowances of the National Research Council, but an important further step has been taken in making additional recommendations for combat and logistically difficult conditions. These levels of nutrients are a goal, then, for ration planning. The second, third, fourth and fifth intermediary links in the chain may be listed as, (2) the planning of food items that are above all else palatable and well accepted, (3) the proper packaging of food items in the form of rations, (4) the procurement in sufficient quantity of the rations, and (5) their delivery in good condition to the troops. These links in the chain are Quartermaster responsibilities (aided by the Veterinary Corps in the case of inspection of animal products) and broadly delineate one of the fields in which Quartermaster Research and Development has made such an outstanding record during the past several years. We then come to the sixth and final link—one which I think we will agree is the ultimate purpose of all of our combined efforts—namely assurance of the health of the soldier, insofar as food is involved. This last aspect, the determination of nutritional state of both military personnel and civilians under military control in occupied countries, represents another one

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

of the important functions carried out by the Nutrition Division of the Preventive Medicine Service in the Medical Department.

This background serves to outline the rather complex character of the problem of feeding the Army. You ask about unsolved problems in Army nutrition. They are many, as indeed this group is aware, even from the standpoint of technological perfection in a single food item. They are many also—even when the question is limited to medical aspects; however, they can be classified roughly into two main categories: (1) those relating to the physiologic requirements for nutrients in order to maintain health, and (2) those relating to the appraisal of nutritional state in order to determine the effectiveness of ration and other feeding.

The requirements for nutrients in order to maintain health have many more aspects than are represented merely by the number of known and unknown nutrients. There is an increasing volume of evidence indicating that the requirement for a nutrient is closely linked with the levels of certain other nutrients also found in the diet. Perhaps one of the best recent examples of this situation is the discovery in animals that apparently low levels of intake of niacin may be adequate to prevent the appearance of deficiency symptoms, provided the protein in the diet is of good quality and of ample quantity. This work indicates further that the effect mentioned is closely related to the level of a certain amino acid in the diet—tryptophane. Thus, symptoms caused in animals due to low intake of niacin may be cured or prevented by any one of a number of mechanisms, such as supplying only the lacking nutrient—niacin, or increasing the level of protein in the diet, or by adding the amino acid, tryptophane. I mention this instance because it serves to illustrate a point which I fear is not as well recognized as it should be in nutritional work. Many of us are inclined to look upon nutrients as being in air-tight compartments, and if one of them is provided in the diet in rather lower quantities than we have been led to believe necessary for health, we begin immediately to expect the appearance of classical clinical signs of that particular dietary "deficiency." As a matter of fact, one of several results may occur under those circumstances—entirely different symptoms from those expected may appear due to the fact that a diet is rarely deficient in a single nutrient (except perhaps calories); or else the treatment of the specific deficiency symptom, when it does occur, may result in the sudden and marked appearance of signs of other unlooked for deficiency; or, as another possibility, no sign of deficiency may occur at all, due to a so-called "sparing" effect of other nutrients in the diet. I think then, that one of our unsolved problems in nutrition may lie in the concepts of the nutritionist himself, should he attempt to dissociate individual nutrients from each other and the effects of those individual nutrients which make up the diet as a whole.

Another general problem concerns the physiologic signs of nutritional deficiency. These may appear as a gross or microscopic lesion, or as a decrease in physical or psychomotor efficiency, or in the form of delayed recovery time from disease or surgery, or in the individual's subjective feeling of a lack of well-being, or lowered morale or some similar vague consideration. These are, however, (or possibly may be construed as being) signs of a need for improved nutrition, and as such, may form a sound basis for therapeutic and further preventive measures. They are a much more solid platform than is the mere comparison of the dietary evaluation with recommended allowances, these latter frequently being referred to or thought of as "standards." I should like to point out that the value of tables of food composition and recommended allowances of nutrients lies primarily in the proper planning of diets, but thereafter these measures hardly constitute an open sesame to proper nutrition. Consider, if you will, the various places where reliance upon the

adding machine as a guardian of health may be thwarted. We all know the widely different levels of nutrients that may be found in a single food item, depending upon species, soil, climate, processing procedures, and storage both before and after processing. Thus, because of the presence of many or all of these factors, canned tomatoes may have as little as 3 or 4 mg. of ascorbic acid per unit of weight or as much as 25 mg. However, in the calculation of the diet, we must choose an average value that will be merely a compromise between such extremes, and we usually rationalize such a procedure by trying to choose the most likely value. Then come the factors related to the general human equation. Improper storage of any type of food, improper preparation or cooking of the foods for long periods of time with much heat or water, followed by long standing times after preparation, all may knock our carefully calculated nutritional health into the proverbial "cocked hat." Then there is the specific human equation, represented by the food habits and preferences of the individual, who in the last analysis decides for himself what he will eat and what he will reject, and therefore really determines his own nutrition. Do you not agree therefore, that while good planning is a necessary preliminary to proper feeding, we should nevertheless avoid being too closely bound by the whimsy of the decimal point, or our trust in a so-called "standard"? I do not suggest discontinuance of work designed to establish dependable tables of average food composition or approximate human requirements, but I do seriously entertain the belief that we should concern ourselves primarily with the production of great quantities of well-accepted, palatable, good quality food, with the vitamin and mineral contents being of somewhat less importance. It seems to be rather obvious that because of the many uncertainties attendant upon dietary evaluation and individual biologic requirements, our chief concern in relation to good nutrition should revolve primarily around the production and consumption of wholesome and attractive foods known to be needed or desired by countries or continents—foods which constitute a well-rounded and well-proven diet—the best rough measure of adequate nutrition.

These points may appear to be somewhat distantly related to unsolved problems in nutrition. However, one's approach to proper nutrition or one's concept of it, determines what the problems are. We need the applicable, rather than the purely academic. It seems to me that human nutrition is one field where we must retain the concept of the whole, rather than buzz about the component parts which give by themselves an untrue picture of what happens physiologically and what our real needs for food actually are.

Turning to some of the specific problems in the category of nutritional requirements, currently important questions arise concerning the lesser known B-complex factors. What is the need by the human for folic acid, pyridoxine, pantothenic acid, biotin, and others? If they are proven to be needed by the human, how much of each is required in the presence of a given quantity of other nutrients, particularly protein? How much can be utilized by the body from the large quantities found in the intestinal contents as a result of synthesis by bacteria? What are the earliest signs that something has gone wrong, metabolically speaking, in the body's procurement of some or all of such nutrients, and what is the physiologically easiest and economically cheapest way of preventing and curing such deficiency states?

The role that intestinal organisms may play in modifying human requirements for nutrients offers fascinating possibilities. We at the Medical Nutrition Laboratory, and our associates at Northwestern University Medical School have been impressed by the fact that when an individual consumes a diet containing low quantities of certain nutrients, there will be a rather prompt drop in the urinary

levels, but usually there is no similar decrease in the fecal levels of those nutrients, even over long periods of time. Indeed, under certain conditions, the levels in the feces may increase to several fold those taken in through the diet. It is of great importance to know whether such nutrients produced by intestinal microorganisms may decrease our requirements for dietary nutrients, or whether they merely remain unavailable in the intestinal tract. If they are absorbed and physiologically available, then it is of importance to know which classes or groups of organisms are responsible for which vitamins and in turn, what types of foods, particularly carbohydrates, influence favorably the presence of the microorganisms. Would it not be startling if we were to find that the carbohydrate content of the diet in addition to being important as a source of energy, is also an influence on other dietary requirements by being important in the production of available vitamins (or amino acids) in the intestine?

Other problems arise in relation to the possible role of the intestinal synthesis of vitamins as a factor in providing some of the nutrients required daily. We immediately question the associated effects of certain therapeutic agents, particularly the sulfa drugs, in relation to modifying the numbers and types of intestinal microorganisms, thus affecting the amounts of nutrients produced in the intestine and possibly absorbed by the body. On the other hand, it is quite possible that such symbiotically produced vitamins may occur in a complex form, perhaps conjugated with protein, so that they may remain unavailable because of the absence of the necessary proteolytic enzymes at the level of the intestinal tract where they seem to be elaborated. Such a possibility would seem to be worth considering when we recall that the rat on a deficient diet will eat his feces presumably in order to split off and absorb the nutrients produced in the intestinal tract by microorganisms.

These are just a few of the problems which arise in considering the lesser-known B-complex factors and the intestinal synthesis of vitamins. One could go on almost indefinitely in considering other related problems.

Then there is protein. The ancients named nitrogenous substances "I come first," that is, protein. As a result of work that has recently been reported, and our own research, as well as the observations made in Europe, we are again reminded of the importance of protein in the diet, not only as the means of providing building substances in growth and reproduction, and replacement materials in adulthood, but also as possibly being one of the fulcrums upon which the adequacy or inadequacy of the overall diet may rest. Such a concept leads to a consideration of the relatively untouched field of amino acid and vitamin relationships, and further, the relationship of endocrine secretion and function to protein and vitamins and minerals. We need to obtain more information as to which amino acids are required by the human for growth, and which ones are required for maintenance after growth has been completed. In the field of physiology, we are at a loss to explain some of the observations recently made in European countries that edema does not always occur as would be forecasted from the presence of low plasma protein levels. It appears that other factors, perhaps cell permeability, or tissue turgor, or some totally unknown factor may require addition to the classical Starling theory of water exchange and its relation to edema formation. These and many other problems which arise in the protein field serve to indicate that even after centuries of research on protein and its functions in the body, new problems and new aspects of old problems arise continually.

Similar problems occur in the field of lipids. It is startling to the stereotyped concept of nutritional requirements to learn from an individual that when he kept

careful record of his fat intake in a prisoner of war camp, he found that it did not exceed ten or fifteen grams a day for long periods of time, and he felt that even after two or three years there were no ill effects. One would be inclined to wonder whether or not "hidden" fat in food had been included in such an estimate, and also to question whether or not the integrity of the tissues was actually unimpaired, particularly those known to be affected by lack of the fat-soluble vitamins A, D, E, and K, as well as certain unsaturated fatty acids. One would be inclined to debate also if decline in body weight was not included in the appraisal, since a deficiency in calories is as much a nutritional deficiency as is the lack of ascorbic acid. Regardless of those questions, however, such a report tends to emphasize our lack of knowledge of the human requirements for fat, and for specific fatty acids, and the problems of the inter-relationships of fat, carbohydrate and protein in the scheme of dietetics.

An interesting problem that has possible application in all walks of life concerns the effects upon physical and psychomotor efficiency of just missing meals. It is important to know what the likelihood of good performance is when one misses a single meal, or several. Does fasting have a temporarily beneficial effect? Is one's mental acuity increased, while physical efficiency is decreased? If such an effect should be found, what type of meal, that is, predominantly carbohydrate, or fat, or protein, would be best—and how much time should be permitted to elapse between feeding and performance? A contribution of great importance has been made to Air Corps operations by a recent investigation of pre-flight and in-flight feeding, and similar possibilities exist for all types of operations or activities. This type of problem, originally suggested to us by Dr. A. C. Ivy, is now under investigation.

The problems of nutrition concerned with susceptibility to and recovery from disease are many, and are important. It is probable that protein, playing the role that it does in the formation of antibodies (and phagocytes), will continue to be found to play a dominant role. However, there has been sufficient work, suggesting that certain vitamins are also involved, to show that there is much yet to be learned. One is inclined to wonder if increased susceptibility to certain diseases may not be one of the outstanding symptoms of nutritional lack. Certainly, the effects of starvation and undernutrition in Europe are reported to have been conspicuously lacking in the form of gross deficiency lesions, but quite obvious in their relation to the high percentage of infectious disease.

Throughout the war, the impression has been gained that caloric deficiency is probably the most likely to be encountered first, and that its effects are likely to be the greatest in causing lowered morale and efficiency. It is my feeling that caloric adequacy should be of prime importance in the provision of food for any circumstance, with protein being second in choice, and vitamins and minerals third. This statement is in no way intended to decry the importance of vitamins and minerals, but merely serves to indicate a gradated importance in relation to time required for the effect to become apparent. Whether or not this concept is acceptable to the reader, I feel that he will nevertheless agree that considerably more information is required than we now have on the "cost of work." We are inclined to feel, I believe, that all caloric expenditures have been worked out, or can be when required, by reference to caloric expenditures listed for standard types of work. The fallacy of this concept only becomes apparent when special types of caloric costs are required, such as in new military activities, or when reduction in food supplies to foreign countries is contemplated. This type of data as well as the caloric value of foodstuffs will always remain an issue of paramount importance in international discussions and agreements.

Before leaving the field of requirements for nutrients, I should like to mention briefly the too frequently deserted field of hospital dietetics. Where does adequate nutrition play a greater role than in restoring plasma and tissue protein in the negative nitrogen balance found after or during illness, surgery, burns, shock, etc.? If we had some means of knowing when it is beneficial to feed protein, or its hydrolysates, this would be of great benefit to the patient. Therefore, some means of determining the end of the "catabolic" stage, and the beginning of the "anabolic" stage in negative nitrogen balance is a project high on the list of things to be investigated by the Medical Nutrition Laboratory. Another problem of great importance arises in overseas operations during time of war, when the only ration available for the wounded patient awaiting evacuation to rear or fixed hospitals may be a combat type of ration. Have you ever considered the problem of how to feed a wounded patient when canned meat and beans, or frankfurters or the like is the type of food available? These food items, and the rations of which they are a part, may be excellent food for the healthy, active and intact combat soldier, but not for the man who has lost quantities of blood, or has a gaping wound, or whose gastro-intestinal tract is "out of order" as a result of diarrheal disease. An important contribution has been made by devising a beverage aid pack, but there remains a lot more that can be done in this field. An interesting possibility for overworked fixed hospitals may perhaps be found in the development of frozen individual special hospital diets.

Let us turn our attention to problems relating to the appraisal of nutritional state. To be able to appraise nutritional state is of considerable military and economic importance. It is not only of importance in preventive medicine to be sure that no sign of nutritional lack exists in troops, but it is also important to ascertain the nutritional status of civilians in occupied or liberated countries as a basis for the feeding program to be put into effect. To date, three types of information have been utilized—clinical, biochemical and dietary history. There is a great deal of investigational work required for improvement and amplification in all of these categories. Some of the most recent contributions are those of Bessey and Lowry who have developed several micro methods for the analysis of very small amounts of body fluids. The combined efforts of the Harvard Fatigue Laboratory and the Medical Nutrition Laboratory in devising methods of compactly carrying equipment and chemicals to far off theaters of operation for the appraisal of nutritional state under field conditions is worthy of note. One of the chemical determinations desired most at present but as yet not perfected for field use is that for plasma vitamin A. One of the most striking advances of all has been made in simplification of methods for determining plasma protein and blood hemoglobin, and this is indeed important because of the tendency for deficiencies to occur in the protein category in diets eaten during time of war, particularly in European countries.

However, the bigger principle of what other biochemical data mean in terms of true tissue nutritional state, physical performance, etc., is a subject of some controversy. There are those who believe that a decrease from so-called normal levels in blood or urine should serve as a sign that if no corrective dietary steps are taken, real deficiency signs may occur. It is true that a change in body chemistry does usually occur before tissue changes, but the problem is complicated by the fact that some people normally excrete high and others low levels of nutrients on similar intakes. Furthermore, there is considerable evidence that such levels, either in blood or urine, are profoundly influenced by the immediately preceding (*i.e.*, a few days) dietary intake, and thus the anomalous situation of a well-nourished person excreting low quantities of nutrients, or the converse, is quite a real possibility. Where the

load or saturation test is used, the problems of rate of absorption and utilization, and the kidney threshold level become other determining factors.

In the clinical category, there appears to be some uncertainty as to the specificity of some of the signs frequently used as indications of nutritional deficiency. Certain signs are usually looked for, including abnormal neurologic response, changes in lip and tongue surfaces, edematous and bleeding gums, increased corneal vascularity, and many others. Without devoting space to the many pro and con arguments as to whether or not such signs can be deemed truly pathognomonic for any single vitamin deficiency, it seems that a good deal of additional work is needed in order to further perfect the clinical diagnosis of the early deficiency states. The type of signs referred to above must obviously be classed as the later signs of a changed metabolism, and only make their appearance following earlier signs, such as impaired ability to do physical work, or a slower response to danger, or lowered morale.

None of the foregoing invalidates the use of either clinical or biochemical data, but merely serves to emphasize the need for cautious interpretation and for continued laboratory work on methods which will be even more sensitive and more accurate than some of those used at the present time. One of the interesting problems now being investigated at the Medical Nutrition Laboratory, and possibly elsewhere, is the inter-relationship in the rat of the fasting urinary excretion or of the load test response of a vitamin with the tissue concentration of that same vitamin in liver, spleen, skeletal muscle, etc., as related in turn to pathologic tissue changes occurring in early deficiency.

The problem of calcium requirement, and how it is modified by phosphorus, vitamin D, protein, and other nutrients is one which still leaves much to be learned. It is true that we know that certain amounts of these nutrients will permit the maintenance of a positive calcium balance in the human. There would appear to be some reason to wonder, however, if the body might not still remain in positive balance by actually drawing upon its store house of calcium (*i.e.*, its skeleton). Such a situation could continue for some time until a great deal of the stored calcium had been used up. There seems to be a need, therefore, for the development of a method for determining changes in the skeleton as related to dietary intake of the minerals, vitamins and other nutrients concerned. The Medical Department is about to undertake an investigation along these lines to determine whether or not it is feasible to utilize the Pennsylvania State College microphotometric technique based on changes in bone density. Should this be found to be accurate and feasible from the military standpoint, it would make a valuable addition to the scope of nutritional survey work, and perhaps to clinical work involving fractures.

I believe that this outline of work being done or yet to be done proves that we are just beginning to make real progress in the field of medical nutrition. As in any investigative work, for each question answered, a score of new problems arise as a direct consequence. This means that we must be alert to the relative importance of each of these problems, and pursue vigorously those which have the best likelihood of promoting health and preventing disease in man. When I am asked about unsolved problems in nutrition, I must confess I would prefer to enumerate the solved problems, for these are the foundation of future work which will further aid mankind.

SOME ARMY CONTRIBUTIONS TO VEGETABLE DEHYDRATION DURING WORLD WAR II

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Many do not realize the magnitude of detail which was required in setting up the Army's dehydration program and making it function adequately during the recent emergency. With the exception of a few items, dehydration stood where it had paused at the close of World War I. Unlike other processed food industries such as canning and freezing, no great sums had been spent on research and development for this industry. Even at the close of World War II, our knowledge of the mechanics, physics, and chemistry of dehydration is far from complete, despite the great progress made during the war years.

The success of the special vegetable dehydration program has been due in no small part to the fine cooperation received from the government agencies, such as the War Food Administration, the Agricultural Research Administration, and the Office of Price Administration, and also to the cooperation received from certain universities, industrial laboratories, and numerous dehydration concerns. To all those who cooperated are due the lasting appreciation and thanks of the armed forces.

PROBLEMS

To understand some of the problems in vegetable dehydration that confronted the government and industry, it is well to take a glance at the situation as it appeared in 1941. At that time there were only a small number of dehydration plants, which were located principally on the west coast and in the Northwest, with a few in the East. The combined maximum production capacity of these plants was about fifteen million pounds of dried product per year, in some of which the Army was not directly interested, such as peppers, spinach, and garlic. No modern individual government specifications for dehydrated vegetables existed. Little was known concerning the varieties most suitable for dehydration. Blanching, though known, was not widely used; actually some dehydrators scoffed at its value. Tests to demonstrate the efficacy of blanching were subject to considerable criticism. The dehydrated product was usually relatively high in moisture content (based on present knowledge and standards) and kept rather poorly. The friction-top can, popular with industry, was not always gas tight. Adequate directions for the preparation and cooking of dehydrated vegetables were practically non-existent.

The advent of the war added new problems—shortages of tin and rubber, which were essential for the manufacture of some of the most satisfactory containers, and shortages of metals, production equipment, control instruments, and other items necessary for the construction and operation of dehydration plants.

CONCURRENT ACTION NECESSARY

The Army planned to procure large quantities of dehydrated products for the purpose of saving shipping space, weight, tin and other packaging and packing materials. It became essential, therefore, to take action on a large number of matters concurrently, especially during the calendar years 1942 and 1943. Of great importance among these were the designation and the organization of personnel in

the Army for planning, supervising, and carrying on the special dehydration program, a program that included the carrying out of plant surveys and inspections and the expansion of the dehydration industry to obtain the greatly increased production required by the Quartermaster Corps and the War Food Administration. Another factor of importance was the organization of government committees to coordinate and control the dehydration activities and to prepare specifications for each product that the Quartermaster Corps intended to purchase. The dissemination of information of many kinds and the rendition of aid to the dehydrators were no small problems. The organization and the supervision of Dehydration Field Supervisors, the preparation of directions for preparing and cooking dehydrated products, and the instruction of personnel concerning these matters, all presented distinct problems. The initiation, coordination, and application of a research program was a task in itself. The estimation of requirements, the preparation and issuance of procurement directives and letter purchase orders which included the initiation of financial investigations of prospective dehydrators, the procurement, storage and shipment of dehydrated items, and the maintenance of liaison with government agencies, dehydrators, procuring depots, manufacturers and others were other problems that required immediate attention.

ORGANIZATION IN ARMY FOR SUPERVISING DEHYDRATION ACTIVITIES

The administration of the special dehydration program of the Army centered in the Office of the Quartermaster General, specifically in the Subsistence Division under Major General Carl A. Hardigg and Colonel Paul P. Logan. The main activities took place in the Subsistence and Military Planning Divisions. However, the Procurement, Storage and Distribution, and Personnel Divisions each contributed substantially to the success of the program.

The initiation of the Army's special program took place in the Subsistence Division, and much of the activity was concentrated in the Office of the Assistant Chief of Subsistence (Colonel Paul Logan) during the first years of the war, and later in the Non-Perishable Branch under Colonel Louis C. Webster. The Dehydration Section (Colonel Cecil G. Dunn, Chief, and Captain Lawrence J. Schiller) was originally a part of the former office, but subsequently a part of the latter.

The Subsistence Division coordinated the special Army program with the War Food Administration and other government agencies, stimulated and aided greatly in the expansion of the dehydration industry, prepared Army specifications, determined requirements (in conjunction with the Military Planning Division), prepared and issued procurement directives, initiated letter purchase orders and financial investigations, initiated and supervised the carrying out of research, inspected dehydration facilities, and aided dehydrators in a wide variety of manners.

The Military Planning Division, Research and Development Branch, was responsible for the carrying out of research concerning subsistence and packaging after December 1942. It was also charged with the preparation of specifications after this date. This work was originally carried out under the direction of Dr. Fred Blanck but later, for about one and one-half years, under Dr. Bernard E. Proctor. Colonel Rohland A. Isker was the last director of the Subsistence Section of the Research and Development Branch and was also in immediate charge of the Quartermaster Corps Research and Development Laboratory in Chicago during the war. Captain William R. Junk spent a great deal of his time on dehydration matters as a member of the Research and Development Branch.

The Procurement Division supplied considerable help on legal, financial, and procurement matters, which included contractual and certificate of necessity problems.

The Personnel Division participated in matters concerned with labor, manpower, and personnel.

The Storage and Distribution Division was in charge of packing and storage.

The Quartermaster Corps Research and Development Laboratory, under the immediate supervision of Colonel Isker, carried out much of the research on dehydration matters undertaken directly by the Army. The Fruit and Vegetable Section, directed by Major Matthew E. Highlands, contributed to product development, preparation of directions for preparing and cooking dehydrated foods, and specifications. The Packaging and Packing Section rendered much help in connection with the packaging and packing of dehydrated products.

Procurement for the Army and the Navy (including the Marine Corps and the Coast Guard) was made through three depots—the Chicago, the California, and the Jersey City Quartermaster Depots. The Chicago Quartermaster Depot procured all the dehydrated vegetables, the California Quartermaster Depot all the dehydrated fruits except cranberries, and the Jersey City Quartermaster Depot the dehydrated cranberries. The depots received their instructions concerning procurement from the Subsistence Division of the Office of the Quartermaster General.

PLANT SURVEYS AND INSPECTIONS

A number of surveys were made of the dehydration industry during the first few months of the war, to obtain information concerning production capacity, facilities, equipment, types of products that could be processed by the plants, packaging materials used, and related matters that would be of aid in expanding the industry. One of the first surveys was made by Dr. Samuel C. Prescott, who was appointed at an early date as a special consultant to the Office of the Quartermaster General. He was joined in his survey by representatives from the U. S. Department of Agriculture, the British Ministry of Foods, and other agencies. Some of the information gained in this survey proved to be of considerable value in the preparation of the first specifications for dehydrated vegetables, which appeared during April 1942 as U. S. Army Specifications. This survey also provided information concerning some of the special problems, such as the need for basic research on many projects and the necessity of instruction for the education of dehydrators.

Plant inspections were made by officers or civilian personnel of the Quartermaster Corps on numerous occasions for the following purposes: (1) to ascertain the general qualifications, equipment, and facilities for dehydration of a dehydrator or prospective dehydrator, (2) to determine the progress being made in preparation for dehydration and to expedite this, (3) to offer advice and help on technical, sanitary, procurement and many other matters of direct interest to the Quartermaster Corps and the dehydrators, (4) to expedite the production of quality products, and (5) to make examinations and obtain scientific data for the purpose of improving the quality of the finished products.

The plant inspections were carried out by officers of the Subsistence Division, the Research and Development Branch, and Dr. Samuel C. Prescott of the Office of the Quartermaster General, by officers and representatives of Quartermaster Corps Research and Development Laboratory and the procuring depots at Chicago, Oakland, and Jersey City, and by the Dehydration Field Supervisors.

EXPANSION OF THE INDUSTRY

The main expansion of the vegetable dehydration industry took place during the years 1942 and 1943. Control of expansion was exercised by the Joint Dehydration Committee (sometimes known as the Central Control Dehydration Com-

mittee), which was made up initially of representatives from the War Food Administration, the War Production Board, and the War Department. The executive Committee of this organization consisted of Mr. E. A. Meyer, Chairman (W.P.B.); Mr. William Meal (W.F.A.), and Colonel Paul P. Logan (W.D.), with their alternates. The Joint Dehydration Committee contained several subcommittees, such as the Packaging Subcommittee, the Specifications Subcommittee, the Commodities Subcommittee, the Research Subcommittee. Meetings were held frequently, often several times a week, during the spring, summer, and fall of 1942.

The Joint Dehydration Committee required that anyone interested in going into vegetable dehydration submit an application containing information of a specified nature concerning his qualifications for entering the field. The main purpose of the Joint Dehydration Committee was to select the best qualified organizations, taking into consideration the following important points: (1) knowledge of food processing, particularly dehydration; (2) possession of building space, boilers, and at least some preprocessing equipment; (3) location in an area of good supply of the items to be dehydrated (location in a city was not usually viewed favorably); (4) financial soundness; (5) suitable transportation facilities; (6) adequate labor supply; and (7) the over-all requirements for a particular dehydrated product. Applications were reviewed by the Committee and were approved, rejected, or held for further consideration. Individuals whose applications were approved were helped in every way possible by the government to get into production. Priorities were granted, and technical and other kinds of assistance were given. Without priority assistance, it was usually impossible for a concern to construct suitable dehydration facilities. Thus it was that the Joint Dehydration Committee was able to control and facilitate to a high degree the expansion of the industry.

Encouragement of individuals to enter the field of dehydration was made by government officials and others. Representatives of the War Department were responsible for the interest of a large number of qualified concerns and carried out a vast amount of investigational work, including the inspection of facilities, financial investigations, and other studies—all before final judgment could be made on an application.

SPECIFICATIONS

At the outbreak of World War II, there were no federal or other government specifications of a modern or detailed character covering the production of dehydrated vegetables. Early in 1942 the Subsistence Division, Office of the Quartermaster General, prepared specifications for dehydrated beets, cabbage, carrots, onions, white potatoes, sweet potatoes, and rutabagas, based on information submitted by experts from the War Department, the Agricultural Research Administration, universities, and other sources. The specifications covered such essential details as applicable specifications, grades, general and detail requirements, inspection, packaging, labelling, packing, and marking. These specifications, which were published as U. S. Army Specifications in April 1942, appeared as Quartermaster Corps Tentative Specifications and subsequently as revisions thereof.

Through the efforts of the Office of the Quartermaster General and the Quartermaster Corps Subsistence Research and Development Laboratory, specifications were soon prepared for dehydrated apple nuggets, cranberries, hominy, baked beans, and other items.

The War Food Administration prepared its own specifications for use in purchasing dehydrated vegetables for lend-lease and other agencies. These specifications were similar to those of the War Department insofar as product requirements

were concerned, there being close cooperation between the two agencies throughout the war on this important subject.

DISSEMINATION OF INFORMATION

One important contribution of the Army and the Agricultural Research Administration was the dissemination of information concerning such items as new methods and equipment, changes in and new interpretations of specifications, packaging, packing, compression, sulfiting, dehydration to new low levels of moisture content, regulations or food orders affecting the availability of vegetables or fruits for dehydration, and changes in directions for preparing and cooking dehydrated products. Once it was established that certain changes or modifications would improve the quality of a product through processing, packaging, cooking or otherwise, no time was lost in getting the information to the parties concerned.

Information was disseminated by representatives of the Office of the Quartermaster General, by the procuring depots, the Subsistence Research and Development Laboratory, the Dehydration Field Supervisors, by visits to the dehydration plants, and by conferences or discussions with representatives from the plants.

Information was also distributed to dehydrators and others in a more formal manner, as described below.

PRESENTATIONS TO DEHYDRATORS AND ASSOCIATED PERSONNEL

A large number of addresses and semi-informal talks were made to audiences of dehydrators, equipment manufacturers, growers, and others.

Each year during the war, formal addresses were presented by representatives of the Subsistence Division, Office of the Quartermaster General, to dehydrators at the annual convention of the National Dehydrators' Association, which was held in conjunction with the Annual Canners' Convention in Chicago. At this time it was customary to present information concerning the qualitative and the quantitative requirements of the War Department for dehydrated vegetables and fruits for the next fiscal year. Thus it was possible for dehydrators to make their plans sufficiently in advance to meet these new requirements.

In addition, two schools for dehydrators were held, one at the Western Regional Research Laboratory, Albany, Calif., and one at Rochester, N. Y.

DEHYDRATION FIELD SUPERVISORS

The Subsistence Division, Office of the Quartermaster General, organized and placed in the field a group of technical experts designated as Dehydration Field Supervisors. Each Supervisor was assigned to a given area covering several states and was held responsible for visiting the dehydration plants in his area at relatively frequent intervals. His primary duty was to expedite the production of quality products under good sanitary conditions. He distributed advice and information on technical matters and procurement. He helped the dehydrators in many problems relating to production, processing, packaging, and packing, and in obtaining raw material for dehydration. He maintained liaison with the Office of the Quartermaster General and the procuring depots, also with other government agencies when the occasion demanded.

The group of Dehydration Field Supervisors organized and supervised by the Subsistence Division included Mr. Joseph Blumlein, Mr. Richard Tobin, Mr. Paul Richert, Mr. Irvin Olsen, and Dr. Bryce Prindle. The group was enlarged by the addition of Lt. Henry Covington and Captain Frederick Cochran of the Chicago Quartermaster Depot. Supervision of the Dehydration Field Supervisors was

transferred to the Chicago Quartermaster Depot in January 1945, in view of the shift in emphasis from technical to procurement matters.

INSTRUCTION CONCERNING THE PREPARATION AND COOKING OF DEHYDRATED FRUITS AND VEGETABLES

As noted earlier, little information was available at the outbreak of the war concerning preparation and cooking of dehydrated products, particularly detailed instructions for preparation by field units. To overcome these shortcomings, the Army prepared, printed, and distributed directions for handling, preparing, and cooking dehydrated products and taught the subject in Schools for Bakers and Cooks.

The Quartermaster Corps Subsistence Research and Development Laboratory, with the cooperation of Swift and Company, formulated the original directions for the preparation and cooking of several dehydrated items. The formulas were given in terms of quantities sufficient for one hundred and for eight men, respectively. The formulas with the accompanying directions were tested at Schools for Bakers and Cooks and edited in the Office of the Quartermaster General. These were published in Technical Manual 10-403 and distributed to the messes overseas. Work was not completed on the first manual before revisions and additions were being made for a new edition.

As a result of a directive issued by the Subsistence Division, Office of the Quartermaster General, in January 1943, printed or mimeographed directions for the preparation and cooking of dehydrated vegetables and fruits were placed in each container. Thus all packages of dehydrated vegetables, except those produced during the first few months of the Army's special dehydration program, contained directions.

The first school for training individuals regarding the proper handling, preparation, and cooking of dehydrated products was conducted for mess sergeants of the Northwest service command. Following this, the Quartermaster Corps conducted two types of such schools. One of these was a school for instructors. The other was a school for cooks. Approximately two hundred of these schools were in operation in this country during the early years of the war. In addition to this type of instruction, teams were organized to tour messes and make any necessary suggestions for improvements. Unfortunately there were some cooks, particularly during the first part of the war, who never received this valuable training because their units moved overseas before it became available.

SULFITING

Sulfiting of several kinds of vegetables prior to dehydration was required by the Quartermaster Corps, to aid in the prevention of deteriorative changes during the dehydration process, in the preservation of the natural color and flavor of the product during storage, and in the retention of ascorbic acid.

The quantity and the quality of the sulfites used were carefully regulated and controlled, to accomplish the purpose of sulfiting and to prevent the use of excessive amounts which would injure the flavor and cause unnecessary destruction of thiamin.

Cabbage was the first vegetable sulfited on a commercial scale in dehydration plants supplying the Army. The sulfiting of cabbage was instituted early in the fall of 1943, in California. Within a few months, all plants producing dehydrated cabbage for the Army were sulfiting. Specifications required a maximum of 1,500 and a minimum of 750 parts per million of sulfite in the dehydrated product.

The Quartermaster Corps began sulfiting of vegetables only after an extremely careful investigation of the entire subject, based on information available in this

country, Canada, and Great Britain. Action was taken at once with the cooperation of the Western Regional Laboratory, the War Food Administration, and the University of California, to develop suitable and accurate methods for measuring the sulfite content of dehydrated cabbage and to devise methods for the application of the sulfite solutions in the dehydration plants. Mr. Paul Richert, Quartermaster Corps Dehydration Field Supervisor, contributed much to this program, as did Dr. Beavens of the Agricultural Research Administration.

After joint research by the Quartermaster Corps Subsistence Research and Development Laboratory and the University of California, it was decided by the Office of the Quartermaster General that carrots processed for the Army should be sulfited before dehydration. Accordingly, carrots were the second item sulfited on a large scale for the Quartermaster Corps. A maximum of 1,000 and a minimum of 500 parts per million, of sulfite in the dehydrated product were required.

Authority was granted by the Subsistence Division, Office of the Quartermaster General, to several plants during the period 1943 and 1944, for the sulfiting of white and sweet potatoes prior to dehydration. In the fall of 1944, action was taken by the Office of the Quartermaster General to commence the sulfiting of white potatoes for the Army on a nation-wide basis, and it was the plan for all dehydration plants to sulfite this product as rapidly as it was possible to install equipment and facilities. By the end of the war, in 1945, a large number of dehydration concerns that produced dehydrated white and sweet potatoes were sulfiting in accordance with instructions from the War Department. The maximum allowable content of sulfites in the dehydrated white and sweet potatoes was 500 parts per million; the minimum was 200 parts per million.

REDUCTION IN VOLUME OF DEHYDRATED PRODUCTS

To save shipping space, tin, steel, packing and other material, resort was had to the following means: compression, agitation, the subdivision of the products into special forms and sizes before dehydration, and tamping.

Research on compression was initiated by Dr. B. E. Proctor at the Massachusetts Institute of Technology in June 1942, at the request of the Office of the Quartermaster General. This led to the accumulation of considerable basic information on the subject and the manufacture of a press by the Baldwin Locomotive Works, which was installed at Modesto, California, for further research. In collaboration with the Quartermaster Corps, research on compression was also carried out by the Continental Can Company, the Pneumatic Scales Corporation, and the Basic Vegetable Products Company of Vacaville, California.

The Army procured hundreds of thousands of pounds of compressed dehydrated cranberries and onions packaged in one-pound blocks. These were most satisfactory. Other vegetables did not lend themselves to this procedure.

Through the use of vibrating platforms, dehydrators were able to place larger quantities of dehydrated root crops into containers.

Vast amounts of shipping space were conserved by requiring the subdivision of root crops into special forms and sizes. For example, the most material could be packaged in a given space when the product was prepared in the form of cubes or half cubes. Julienne strips generally required more space per given weight, and slices required the most. After the first few months of the war, all the carrots and most of the beets, white potatoes, sweet potatoes, and rutabagas were purchased in cubed or half cubed form. The cubed and half cubed forms were procured only after careful tests had been carried out to prove that such forms could be prepared, cooked, and served without loss of desired characteristics. It was necessary to

specify the sizes of a given form which the dehydrators could produce. Products of small particle size were oftentimes objectionable. For example, dehydrated precooked shredded white potatoes, when ground to a small particle size, could be packaged in considerably greater quantities than the original dried shred, but such material, when cooked, was pasty and highly undesirable. Research by the Quartermaster Corps has shown that a size of shred permitting the packaging of about 15 pounds per can of 5-gallon capacity is satisfactory.

Tamping was developed for the purpose of increasing the density of such products as dehydrated cabbage and onions. The use of this procedure practically doubled the amount of these items that could be packaged in the 5-gallon container.

The successful application of agitation, subdivision and tamping, and the greater availability of shipping space relieved the government of the necessity of going into the widespread use of compression, which would have added a substantial increase to the cost of producing some of the items.

RESEARCH

Research concerning vegetable dehydration and its associated problems was initiated by the Subsistence and Military Planning Divisions of the Office of the Quartermaster General and carried out as military, joint, or cooperative projects in (1) Army facilities, such as the Quartermaster Corps Subsistence Research and Development Laboratory, Camp Lee, or selected Schools for Bakers and Cooks; (2) colleges and universities, such as the University of California, the Massachusetts Institute of Technology, the Louisiana State University, the University of Maine, the University of Maryland, and the Oregon State College; (3) commercial laboratories; (4) the laboratories of industrial concerns, for example, the container manufacturers; (5) the laboratories and plants of dehydration concerns; and (6) government laboratories, particularly of the Agricultural Research Administration and the War Food Administration, with special reference to the Western Regional Research Laboratory and the Processed Products Standardization and Inspection Division.

Research was initiated and carried out on a wide variety of subjects concerned with vegetable dehydration, for example, on packaging; on packing; on compression; on blanching and tests to determine its efficacy; on the effect of the form and size of root crop subdivision on its dehydration, reconstitution, cooking, palatability, and packaging; on the effect of low moisture on keeping qualities; on in-container dehydration; and on analytical methods. Additional investigations included the determination of some causes of the darkening of white and sweet potatoes during the process of dehydration and the prevention of this discoloration; the sulfiting of vegetables prior to dehydration; the bacteriological examination of dehydrated foods and the equipment and facilities of dehydration plants; the improvement of trays; the nutritive value of dehydrated vegetables and other items; and the effect of cooking in different manners on the nutritive value of dehydrated foods. Development of new products, such as dehydrated granular white potatoes, blueberries, and baked beans, and their preparation and cooking received much attention.

INCREASED STORAGE LIFE THROUGH LOWER MOISTURE CONTENT

The relationship of moisture content to the storage life of dehydrated vegetables and fruits was recognized at an early date by the Quartermaster Corps, and action was taken repeatedly to reduce the moisture contents when this could be done without injury to the products or without interfering with production severely. Before requesting a reduction in moisture to new low levels, it was necessary to determine whether the dehydrators could accomplish this without sacrificing quality or too

much production capacity. This meant surveys and laboratory examinations and then changes in the specifications.

In-container dehydration was of much interest to the Army, which worked closely with the Western Regional Research Laboratory on this project. Plans were in progress for requiring the packaging of large quantities of dehydrated vegetables in this fashion, when the war terminated.

NUTRITIONAL STUDIES

Only a few months after the inception of the Army's special dehydration program, arrangements were made with the National Research Council to carry out research concerning the nutritive value of dehydrated products. Over a period of many months, hundreds of samples of dehydrated vegetables and soups were furnished to this agency for analysis. This program has been completed, and the results are available through the National Research Council.

Other cooperative studies on the nutritive value of dehydrated foods have been carried out for the Army at the University of California, at Cornell, and at other laboratories.

BACTERIOLOGICAL INVESTIGATION

Extensive preliminary bacteriological investigations were carried out by the Quartermaster Corps to determine the relationship of the bacteria found on dehydrated vegetables and on equipment to the quality of the products and the sanitation of the plants. Considerable valuable information was gained from these studies and applied.

In closing, the authors wish to express their sincere appreciation to all connected with the Armed Services special dehydration program during World War II. We should also like to indicate that, although great strides have been made in the improved knowledge and production of dehydrated fruits and vegetables, we believe that much remains to be done in this field.

ENGINEERING ASPECTS OF DEHYDRATION IN THE ANHYDRATION PROCESS [1]

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"Dehydration" means "to remove water from." Thus, broadly speaking, a large percentage of our foods are at least partially dehydrated, *e.g.*, grains, prepared cereals, field-dried legumes, sun-dried fruits and fish, smoked meats and meat products, fruit concentrates, condensed milk, and dried vegetables.

Although the primitive people before history's dawn had neither the technological knowledge nor the apparatus available to us moderns, they nevertheless employed many of the principles that were used to produce the dehydrated foods for the fighting men of World War II. For instance, the primitive inhabitants of our desert states preserved strips of meat by hanging them to dry in the smoke of their camp fires—thus anticipating our methods of producing smoked meats and fish. Capelin, a smelt-like sea fish abounding on the Labrador coast, has since time immemorial been preserved merely by spreading the whole fish on rocks by the seashore—exactly anticipating the methods still used for producing almost all of the modern world's supply of dried fruit. Long before the Pharaohs, meats, seafoods, and grains were slowly desiccated on platforms under which small fires were kept burning—in almost the exact way in which malted barley and many fruits are dried on kiln floors in anno Domini 1946. Primitive drying by exposing foods to warm arid winds anticipated, and in many ways was an improvement upon, our most modern dehydration tunnels. Even dehydration by sublimation was used by natives of very cold northern climates, who hung foods outdoors to "freeze dry."

Many steps in the refinement of primitive drying methods are set forth in the more than 2000 United States "dehydration" patents which have been issued during the last century. For example, in 1849 a patent was issued to Claude Birdseye for his process of pan-concentrating milk.

For obvious reasons, this paper cannot cover the engineering aspects of all kinds of food dehydration and it is therefore confined principally to the problems of vegetable drying. Moreover, since I am not an engineer, my treatment of this subject will necessarily be imperfect and will contain much of the layman's point of view and language.

TUNNEL DEHYDRATION

During the last several years substantially all vegetable dehydration in this country has been carried out in tunnel dehydrators which are in essence merely insulated wind tunnels in which the products to be dried are exposed to currents of artificially heated air. Approximately 200 million dry pounds of vegetables were tunnel-dried during 1944.

Tunnel dryers are of two general types—those in which the product is carried on trays stacked on wheeled trucks and those in which the vegetables are conveyed on mesh belts. In the former, the dehydrating air passes principally over and between the trays; while in the latter, the air currents pass through the mesh belts and the product thereon. The tray-tunnel type of dehydrator is used much more extensively for vegetables than is the belt type.

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[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

In tray-tunnel dryers, the dehydrating air may enter at the wet end and flow in the same direction as the product, at the dry end, or at both ends simultaneously. In concurrent dryers the entering air may be relatively hot without danger of scorching the product, but it quickly becomes so cool and moisture-laden that it can perform very little work at the dry end of the tunnel. In the counterflow type of dryer the entering air must be very dry and must not be more than a few degrees above the critical temperature of the product being dried. In this counterflow type, the relatively cool air entering the dry end quickly becomes so cool that it can perform little work on the wet product. In the third type, air is forced into the tunnel at both ends and removed near the middle of the tunnel. This method is a real improvement over both of the preceding types but does not altogether solve the problem of air flow.

For efficient operation, all tunnel-type dehydrators require careful control and balancing of many factors, *e.g.*, air temperatures, velocities, volumes, humidities and distribution, and regulated quantities of product.

In tray-tunnel dryers, the product units are spread in thin porous layers on trays with air-pervious bottoms, and the product remains undisturbed in those layers until removed from the dryer. This feature of the process has obvious disadvantages. For example, great care must be taken to prevent thinner and more exposed pieces of product from drying and overheating before thicker and less exposed units in the middle of the mass are sufficiently dry.

Because all of the heat furnished to the product in tunnel dryers must be carried by the air current, very large quantities of air must be circulated. Recirculation of the air is employed to obtain greater efficiency but does not greatly lessen the total amount of air which must be circulated.

For reasons pointed out above, air entering the tunnel dehydrators even at the wet end is usually not hotter than from about 180° to 210° F. and is quickly cooled by the work it performs. At these low temperatures, the air can absorb and carry away only minute quantities of moisture per cubic foot so that very large amounts of air are required for this purpose, also.

Because of the relatively large cross section of the paths through which air is circulated in tunnel dehydrators, velocities are relatively low—seldom more than 750 f.p.m. between the trays—and very much less than that within the product layers. Moreover, because the product units rest constantly one on another, only a relatively small percentage of the product area is exposed to the currents of dehydrating air. Both these factors make for slow drying.

In tunnel dehydration the surface of each product unit is hotter than its interior, and moisture is therefore moved very slowly from the center to the surface of each piece. Accordingly, great care is required to prevent over-drying, or "case hardening," of surface areas before sufficient moisture has been removed from the inner parts of the pieces.

In this type of drying, removal of moisture is at first relatively rapid but becomes greatly retarded as the residual moisture content of the product is lowered beyond eight or ten per cent. Therefore, in order to increase plant capacity, it is common practice to remove partially dried vegetables from the tunnels and to finish the drying by forcing dry air through the product mass while it is held in large bins, usually shaped like an inverted truncated pyramid. In the bins, air velocities are low and uneven and temperatures must be no higher than the critical temperature of the dry product.

All of the above features of tunnel drying make for relatively slow moisture removal. It is not surprising, therefore, that total drying times for most of the

vegetables dehydrated in this country during the war were from about ten to twenty-four hours, of which the product was in the tunnel apparatus for from four to eight hours and in the finishing bins the rest of the time. In some arid climates and with some products, bin drying is not necessary.

ANHYDRATION

"Anhydration" is, of course, a synonym for "dehydration" and has been adopted to designate foods prepared by the process and apparatus described hereinafter.

My personal interest in food drying originated about 1927 in connection with the utilization of by-products from quick freezing, and during the last fifteen years I have tried most of the known ways of getting water out of foods. Prior to 1940, I decided that there would be a worthwhile institutional and consumer market for a line of very high quality, quickly prepared, and inexpensive household fruits and vegetables if such products could be produced. In 1942 I visited most of the vegetable dehydrating plants then in operation and was convinced that the processes and apparatus in use by them were not suitable for my purpose. I thereupon undertook to devise a process and apparatus which would produce the quality of dehydrated vegetables which I believed would meet with public acceptance in competition with the best grades of fresh, canned, and frozen products.

After consulting with a large number of housewives, I came to the conclusion that successful dehydrated vegetables would have to be sufficient in number to absorb approximately seventy-five percent of the housewife's total expenditures for vegetables, approximately the same shape to which consumers were accustomed, colorful and attractive in appearance, capable of rapid and simple preparation for the table, indistinguishable from fresh products when served, and available the year around at prices within the reach of consumers in low income brackets.

Speedy drying would be essential in producing vegetables having these characteristics and such speed was apparently not possible with existing tunnel dehydrators, for every single factor in their operation made for slow rather than rapid moisture removal. It was therefore necessary to reassess the drying problem and to work backwards from the objective of very quick water removal. Research indicated a process diametrically different from tunnel drying. Instead of undisturbed layers of product on trays or belts, the new process would have to tumble and stir the food at frequent intervals to expose the entire surface of each piece to the current of dehydrating air and to prevent the individual pieces from adhering to one another. Instead of supplying the necessary heat by convection only, radiation and conduction would have to be used to facilitate heating the product and to cause the product units to be hottest near their centers. This last feature would force rapid and continued movement of water to the product surfaces, whence it could be readily evaporated. The new process should employ a current of dehydrating gas which would enter at the "dry" end of the apparatus and leave from the "wet" end, meanwhile constantly increasing in temperature.

Although the foregoing characteristics would assure relatively rapid drying of the whole food mass, the smaller or thinner pieces of product would be overheated before the larger pieces were sufficiently dry. To remedy this defect, the movement of dehydrating air would have to be in the same direction as the product at all times where the two were in contact, and air velocities would have to be sufficiently high to bring about a positive winnowing action which would carry product pieces through the process at a speed proportionate to their surface-to-weight ratio and thus automatically prevent the overheating of relatively light products and insufficient drying of thick, heavy pieces. Finally, for the common step of bin drying the new

process would substitute alternating periods of quiescence in relatively still air and violent tossing in high-velocity air.

THE ANHYDRATOR

As will be appreciated, much difficulty was experienced integrating a process and developing an apparatus which would automatically and inexpensively employ all of the above steps. As a result of the construction and testing of numerous preliminary models, the following commercial equipment—called an anhydrator—has been evolved.

The anhydrator consists essentially of five superposed belts carried on a frame approximately forty-five feet long and five feet wide, housed in an insulated room whose outside dimensions are about fifteen by sixty feet. Wet product direct from a continuous blancher is deposited on the receiving end of the uppermost belt, travels the full length of each belt, passes downwardly from one belt to another, and emerges at the bottom of the machine at the opposite end from that at which it entered. Each belt operates in a tunnel, the upper four tunnels constituting a rough drying area and the final one a sort of continuous finishing bin. Heated air enters the feed end of the lowermost tunnel and travels upwardly through the apparatus, passing through each tunnel in the same direction as the product flow.

In the roof of each tunnel is a radiator which both sheds infra-red energy upon the product being dried and continuously heats the dehydrating air passing through the tunnel. Blast heaters are so arranged that the air passing into each tunnel can be reheated to any degree.

Nine fans are used to force air through the apparatus. Of these, one feeds heated air at the highest permissible temperature to the feed end of the lowermost tunnel. Three additional fans are utilized to force the air upwardly and downwardly through the lowermost belt and the product on it, the upwardly moving air being forced through a relatively narrow slot at sufficiently high velocity to separate each product unit from its fellows and to toss the mass of units into the air as it advances to the edge of the air slots. Air passing downwardly through the product is much slower. Booster fans are located at the feed ends of each of the upper four tunnels. Finally, the discharge fan at the top of the machine exhausts to the atmosphere any air which is not recirculated.

Ducts and louvers at the end of each tunnel permit any desired portion of the air from that tunnel to be forced upward into the next tunnel or bled outwardly into the insulated room, which serves also as an air mixing chamber. Louvers in the sides of the tunnels near their discharge ends permit further bleeding of air from the tunnels. By these means, ready and absolute control of air velocities and temperatures in each tunnel may be had. Temperatures in the lowermost tunnel will run from about 100° to 200° F., depending on the product being processed, and will increase to from 250° to 600° in the top tunnel.

All of the belts in the anhydrator are of stainless steel Fourdrinier wire netting of standard 32 by 40 mesh. The belts in the four upper zones are treated with a high-temperature-resistant synthetic which fills the mesh and so prevents fine product particles from passing through and lodging under the upper belt run.

Tedders are located at frequent intervals over each of the belts and operate to stir the passing product mass and to separate each unit from the others gently but positively. This stirring action serves several purposes: it prevents product units from aggregating; it changes the positions of the product units with relation to each other and to the upper and lower surfaces of the product layer; and it tosses the product units into the air stream to facilitate the winnowing action described below.

A flat heating unit is located in the lower part of each tunnel in such a manner that the upper runs of the belts are dragged over and in direct contact with the heaters. In this manner the product is heated by conduction.

Winnowing, or selective advance of the product pieces through the anhydrator, is obtained by the use of high-velocity concurrent airflow in the upper four tunnels. Additional winnowing action is obtained when the product falls downwardly from the discharge end of each belt through the air blast feeding the next lower tunnel. Because of the winnowing action, each product unit passes downwardly through the machine at a speed more or less proportionate to its surface-to-weight ratio. Thus in such products as cabbage, stem pieces may remain in the four upper zones for as much as forty minutes, but leafy portions may blow through all four tunnels in as little as two minutes. In the fifth or final drying tunnel, winnowing is replaced by tumbling and all product units, regardless of their size or shape, remain in that area for the same length of time.

Although it is perhaps too early to speak of "standard" anhydrators, the first lot of five commercial machines now being built by the Cleaver-Brooks Company of Milwaukee will have an evaporation capacity of from 2000 to 3000 pounds per hour, depending on the nature of the product and the temperatures employed. Steam at from 100 to 250 p.s.i. will be used to furnish heat to the several parts of this first batch of anhydrators, but future machines will be adapted to the use of direct combustion gases or electricity.

The anhydrator is, of course, designed for use in drying only those products which are composed of an aggregation of discrete units varying in size from coarse meals to sliced fruit. It is not suitable for dehydrating pasty masses or fluids. Drying times are much less than in tunnel dehydrators. Carrots, cabbage, diced potatoes, and small fruits can be reduced to from 2.5 to 4 percent residual moisture in an average of one and one-half hours.

OTHER USES FOR ANHYDRATORS

Although the process and apparatus described above were developed primarily for dehydrating fruits and vegetables, tests have indicated that they can be used advantageously for many other food products and a number of non-food materials. For instance, grits used in making rolled or crushed breakfast cereals can be dried in an hour or less; noodles and short macaroni can be reduced to 13 percent residual moisture in a few minutes without checking; citrus peel of very fine color, high vitamin retention, and unique pectin yield have been produced; apple, grape, and other types of pomace can be dried quickly without scorching; and granulated synthetic rubbers and other resins can be handled advantageously.

Thus the engineering features which have brought about faster dehydration of vegetables seem equally applicable in many other fields of industrial drying.

RECENT ADVANCES IN THE PRODUCTION AND HANDLING OF DEHYDRATED FRUITS[1]

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INTRODUCTION

Until about 1920 most dried fruit produced in California was evaporated in the sun. Although the disadvantages of sun drying were known, it required heavy financial losses due to early fall rains to induce a large scale construction of tunnel dehydrators. The use of these driers gave insurance against losses from rain damage and at the same time resulted in an improvement by elimination of field contamination and infestation. The use of dehydration for prunes increased from year to year until at present over 80 percent of the crop is dehydrated. Apricots, peaches, pears and nectarines on the other hand continued to be dried in the sun because when dehydrated, the dried products were slightly different in color from that to which the trade was accustomed. Although these difficulties have been overcome in the last few years, the dehydration of these fruits is still on a very limited scale. Natural (dark) raisins attain the desired color only when dried in the sun and so are not dehydrated at present. Golden bleached (light color) raisins, however, have always been made by the use of dehydration. These raisins were developed primarily for the British and other European markets. In the production of golden bleached raisins, seedless grapes are washed, dipped in a lye solution, sulfured, and then dehydrated. During the war the production of this product increased considerably when it became necessary to divert tonnages normally scheduled for fresh shipment or use in wineries to the manufacture of raisins.

Apples have been dried in natural or forced draft evaporators (kiln driers) for years, but the use of dehydrators is comparatively recent.

Prior to the war clingstone peaches were dehydrated commercially on a small scale. In some instances the fruit was cut, peeled, sulfured and dehydrated, whereas in others peeling was omitted. During the war the dehydrated blanched clingstone peach was introduced by Mrak, *et al.* (1943). Although a superior product, it is somewhat more costly to produce than the other types of dehydrated clingstone peaches. The dehydration of figs has been increasing because of the improvement in quality resulting from the elimination of drying yard spoilage.

Practically all walnuts are dehydrated today. It is an insurance against rain damage and spoilage occurring while on the sun drying field. During the war considerable attention was directed toward the dehydration of huckleberries, cherries and pineapple, but commercial production was never attained. Cranberries were successfully dehydrated on a commercial scale during the war. Powdered or sliced dried cranberries form an attractive and promising new product.

The remainder of this paper will be limited to technological advances which have resulted in improved quality and storage life.

HARVESTING PRACTICES

The final quality of the dried product is dependent to a great extent on the condition of the fresh fruit. For example, the flesh of fresh prunes may discolor or develop gas pockets while on the trees or the ground prior to picking. Such deteri-

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

oration is particularly manifest when improper harvesting practices are used or if the weather is unusually warm during the final stages of maturation.

It is an interesting fact that prunes of the same variety when grown in the coastal areas of California fall from the trees as they mature while those grown in the hot interior valleys of the state fail to form an abscission layer. In the first case shaking of the trees is hardly necessary prior to the third picking. In the second case it is necessary to knock the fruit from the trees by use of shaking poles. During the war years mechanical tree shakers and harvesters were developed and are in use at present. As the fruit falls from the tree it drops into a canvas funnel-like collector, which empties into a standard lug box. This eliminates soil contaminations, a marked step in sanitary improvement. If care is not taken, considerable immature fruit can be shaken from the trees. These prunes are low in sugar and mold easily when dried. They also tend to develop a chocolate color and sometimes gas pockets. These conditions are referred to in the industry as "chocolates" and "bloaters" or "frogs" and are much more prevalent during sundrying than in dehydration. On the other hand, according to Pitman, Nichols and Mrak (1934), when interior valley prunes are allowed to remain on the tree beyond the mid-season one can observe a gradual decline in quality as is shown in Table 1. Data indicate considerable variation in quality of prunes grown in different districts. This is shown by the following differences in sugar content of prunes from the three important districts (percent at 20 percent moisture): Santa Clara 52.09; Sacramento 46.87; San Joaquin 40.26.

TABLE 1

Average Weight of Components of Prunes Harvested at Various Dates

Location	Average weight in grams by dates							
	7/18	7/25	8/8	8/31	8/27	9/10	9/11	10/11
Colusa								
Per fruit	13.45	16.40	17.00	13.90	16.80	12.95	11.95	6.60
Per pit	0.95	1.00	0.90	0.85	0.85	0.85	0.90	0.75
Per flesh	12.50	15.40	16.10	13.05	15.95	11.55	11.05	5.85
Total solids	1.89	2.73	3.67	3.04	4.35	3.75	3.72	3.75

Prunes grown in the cool coastal counties are usually richer in sugar than those produced in the warmer interior valley. Experiments conducted by Fisher and Hatherall (1933) have found it possible experimentally, to grade fresh prunes by the use of brine flotation separation, although such a practice is considered economically unfeasible.

An extensive study of the relation between harvesting time of grapes and the quality and yield of the finished raisins has been made by Jacob (1942 and 1944). (See Table 2.) The yield of seedless raisins was found to be proportional to the Balling degree of the fresh grapes. Because of the presence of seeds in muscat grapes the increase in yield lags slightly behind that indicated by the Balling degree of the grape juice. With both varieties, as grape maturity advanced there was an increase in size, weight per unit volume, and sugar content of the raisins and a decrease in percentages of acid and insoluble solids. The changes in sugar and insoluble solids in raisins nearly ceased when the grapes reached 23° or 24° Balling. Quality improved as the grapes ripened. Jacob also stated that picking should start soon after the grapes reach 23° Balling. He indicated, however, that for golden bleached raisins, yellow color of the fruit is a better index of proper maturity for harvesting them than is the Balling degree of the juice.

Apricots and peaches must be fully mature and picked from the tree by hand for drying. In certain areas it is customary to shake apricots from the trees and then pick them from the ground. Harvesting tests have shown that the producer receives greater returns when this fruit is picked from the trees than when picked from the ground after shaking.

Bartlett pears differ from most fruits in that they must be harvested from the trees before mature, and allowed to ripen in the box if satisfactory quality is to be obtained. Ethylene gas can be used to speed the ripening of harvested pears, although this treatment is seldom used on fruit to be dried. A more common practice is to stack immature pears near mature fruit, intentionally or accidentally, where escaping ethylene gas from the mature fruit tends to ripen the immature pears stored nearby.

TABLE 2

Influence of Maturity on Sugar Content and Quality of Golden Bleached Raisins

Average maturity of grapes ° Balling	Quality score *	Average maturity of grapes ° Balling	Sugar content percent †
17.4	....	.....	.....
18.2	....	17.8	69.3
21.6	50	19.6	71.4
22.9	50	21.0	70.4
23.3	50	22.0	70.9
24.5	58	24.2	72.0
25.1	68	24.7	71.9
26.5	78	20.9	71.8
26.8	....	28.0	71.8
27.0	81	29.7	71.7
28.2	92	.....	.....
29.7	92	.....	.....

* Basis of scoring: Best possible grade = 100; second grade = 75; third grade = 50; fourth grade = 25; unmerchantable = 0.

† Expressed in percentage of the raisins at 15 percent moisture content.

Only a few years ago the use of hormone sprays in the orchard to prevent the early drop of pears before harvesting was introduced. This practice is used quite extensively today. Allen and Davey (1945) have found that hormone sprays cause undesirable pears to remain on the trees until harvested; by undesirable pears is meant those fruits which would ordinarily drop early because of insect injury, physiological or anatomical defects. It is difficult for the picker to differentiate between sound and unsound fruit so all are picked and stored mixed together in boxes. The unsound pears deteriorate rapidly and apparently are unsuitable for drying, canning or eating fresh. This problem is confronting the industry at present, and it appears that the solution will be in following an intelligent spraying and harvesting program.

Walnuts fall naturally or are shaken from the trees with long poles, and are always picked from the ground. The outer fleshy shells (the hulls) are ordinarily loose and easily removed by the time the nuts have fallen from the trees. In certain warmer areas, however, if walnuts are permitted to remain on the trees until sufficiently mature to fall naturally, the fibrovascular bundles throughout the pellicle or skin covering the nut meat darkens and the value of the dried product is appreciably less. Since the retention of a light color is essential for walnuts to be placed in a good quality grade the fruit is harvested sufficiently early in these areas to obtain the desired light color. When this is done the hulls adhere tightly to the hard shell. This hull is then induced to loosen by exposure to ethylene gas in accord-

ance with the procedure outlined by Sorber (1939). Hulls have no commercial value at present although they are extremely rich in ascorbic acid.

It is needless to say that even though fruit is harvested at the proper stage of maturity, subsequent treatment during transportation to the drying plant may result in considerable loss in quality. In a few instances in California, apricots have been transported by truck over a hundred miles, and peaches as much as two hundred to the dehydrator. Although there is little reliable information to show the extent of losses in quality resulting from this practice the industry is aware that deteriorative changes do occur in transportation. It is reasonably safe to assume that precooling and icing treatments will be tried in the near future in an effort to minimize these losses even in trucking.

PRETREATMENT

All fruits are subjected to some type of pretreatment prior to dehydration. Whole fruits are washed and sometimes dipped; cut fruits are cut, sometimes peeled, sulfured and in some cases blanched. Persimmons, however, are neither sulfured nor blanched. Walnuts are shelled and washed.

When prunes are sundried it is essential that they be dipped in a ¼-¾ percent lye solution for 15-30 seconds in order to remove the waxy bloom and check the skin with many minute cracks to facilitate drying. When the dehydration of prunes was introduced this practice was carried over and followed until quite recently. Some operators maintained that because of the presence of the many small skin checks resulting from the lye treatment bleeding or exudation of the juice during dehydration was excessive. In view of this certain operators abandoned the use of lye in favor of hot water to cleanse the fruit and remove the wax without checking the skin. It was maintained that the fruit dehydrated equally as fast as fruit with checked skins, bleeding was minimized and the quality of the final product was in no way impaired. Later, only a cold water wash was used in some plants with satisfactory results, although the cleansing action is not as good as when hot water is used. This was rather surprising since it had always been assumed that unchecked prunes would "case harden" by drying most rapidly near the surface, thereby forming a surface layer relatively impervious to moisture. Under such conditions the flesh near the pit would remain moist during dehydration. Eventually during storage this excess moisture diffused slowly to the surface and caused conditions allowing mold growth. Moses (1942) supported the contentions of the commercial operators using the hot or cold water dips. He dehydrated prunes as harvested, after dipping in cold or hot water, a lye solution or passing over a prickle board to puncture the skins. He could see no appreciable difference in the drying times resulting from the aforementioned treatments. In one case the fruit was even peeled and dehydrated without any appreciable effect on drying time. These results may be explained on the basis of data secured by Perry (1944) showing that the drying rate of prunes is proportional to the free moisture ratio in the usual drying range.

In the production of golden bleached raisins (sulfured and dehydrated raisins), however, Thompson seedless grapes are treated with a ¼-½ percent hot lye solution for 5-15 seconds before sulfuring. It facilitates drying and sulfur dioxide absorption. By this procedure the skins are checked and the bloom is removed. After dipping and washing the checked areas tend to discolor rapidly. Hussein, Mrak and Cruess (1942) found that the oxidase activity of these grapes was stimulated by a 5-second dip in hot lye but was greatly reduced when the dip was extended to 30 seconds. The behavior of the enzyme was similar when hot water was used as a dipping bath, Table 3. If in the latter case the temperature of the water was lowered from 205° F.

to 180° F. it took more than twice as long to reach the same degree of inactivation. Unfortunately, it is not possible to use the longer dip on Thompson seedless grapes because of over-checking and "mushing" of the fruit. Furthermore, any discoloration resulting from oxidase activity in the case of Thompson seedless grapes, bleaches out during sulfuring and leaves no noticeable effect on the final dried product.

TABLE 3

Effect of Various Dipping Treatments on Enzyme Activity of Thompson Seedless Grapes

Type of dip	Dipping period	Percent increase or decrease in oxidase activity
Cold dip *	2 minutes	—2.6
	5 minutes †	—34.8
	10 minutes	—45.0
No dip (check)		.....
Mixed dip ‡	5 seconds †	+15.8
	30 seconds	—28.0
	60 seconds	—64.5
No dip (check)		.....
Soda dip (5% solution of NaOH)	5 seconds †	+14.2
	30 seconds	—94.0
	60 seconds	—99.0
No dip (check)		.....

* An emulsion containing 950 grams of alkali mixture (95 grams of Na_2CO_3 and 855 grams of K_2CO_3) and 100 cc. of olive oil and about 20 liters of tap water.

† Dipping periods commonly used in commercial practice.

‡ An emulsion containing 68 grams of K_2CO_3, 34 grams of NaOH, 50 cc. of olive oil, and 12 liters of tap water.

Untreated grapes absorb SO_2 more slowly (Table 4) than dipped grapes and likewise retain it better during drying. The drying time for untreated grapes is greater by several hours than for the dipped grapes. Muscat grapes have not been sulfured prior to dehydration.

TABLE 4

The Effect of Skin Condition of Thompson Seedless Grapes on Absorption of Sulfur Dioxide During Sulfuring *

Sulfuring period minutes	SO_2 absorbed during sulfuring parts per million	
	Skins checked	Skins in natural condition
35	3650	1050
60	3800	1770
95	7490	354

* Sulfured at 100° F. in 17 percent SO_2 by volume.

In (1943) Mrak, Phaff, Fisher and Mackinney described a new method for the dehydration of various cut fruits other than apples. The process involved steam blanching after cutting. The principal objects were to introduce a procedure enabling the industry to produce a dried fruit superior in nutritive qualities and free of dust, dirt and other dry yard contaminations. As stated in the introduction, when steam blanching is omitted the dehydration of sulfured cut fruits results in a product that is opaque, chalky and quite strikingly different from the sundried fruit. The difference

is most pronounced in firm, slightly immature fruit. Furthermore the rate of dehydration is then relatively slow and so-called "case hardening" results easily.

It was found that a superior product of translucent appearance and good color can be prepared if cut fruits to be dehydrated are peeled, and steam blanched prior to sulfuring. In addition, blanching reduces the drying time by 20 to 50 percent depending on the type and maturity of the fruit. The outward appearance of fruit treated in this manner is quite similar to that dried in the sun, except that it is cleaner. When slightly immature fruit is used, the blanched dehydrated product frequently shows a faint greenish cast due to stabilized chlorophyl which the sun normally bleaches out when the halves are exposed in the dry yard. The translucent appearance of blanched fruit is due to a removal of intercellular air pockets which are subsequently filled with fruit juice (Crafts 1942a and b). Vitamin C retention during the dehydration process is superior to that of sundried fruit. Haas and Phaff (1944) determined vitamin C retention by apricots and clingstone peaches after each step in preparation as well as after drying. Losses during preparation, blanching and dehydration are relatively small but considerable during sun drying (see Tables 5 and 6). These data do not mean, however, that the dehydration process will protect cut fruits against subsequent losses during storage.

TABLE 5

Retention of Ascorbic Acid by Peaches During Drying

Treatment	Ascorbic acid	
	Fresh (mgm./100 gm. dry wt.)	Dried fruit (mgm./100 gm. dry wt.)
Sulfured, sundried	52	34
Blanched, sulfured, sundried	68	39
Sulfured, dehydrated	52	64
Blanched, sulfured, dehydrated	52	60

TABLE 6

Ascorbic Acid Retention by Apricots During Preparation

Point in operation	Ascorbic acid	(mgm./100 gm. dry wt.)
During cutting	76	76
Before blanching	78	76
After blanching	76	76

Blanching may be accomplished by use of continuous or cabinet blanchers, the engineering aspects of which have been discussed by Perry, Marsh and Phaff (1945). The continuous blancher permits a more uniform heat penetration, and has a steady demand for steam. The principal advantages of the cabinet blancher are that it occupies only a small floor space and can be built readily of noncritical materials. However, it has a large periodic range in steam demand and also is unsuitable for fruits such as apricots requiring only a short blanch. In addition, careful supervision is required with the cabinet used in batch operation, attention being needed at the start and finish of each batch.

Blanching time varies with the kind of fruit, its size, maturity and variety. It also depends upon the rate of heating in the blancher and the rate of cooling on trays after they are placed on the truck. The latter is influenced by factors like tray length, width of opening between trays, double or single cars, hydraulic loading pits and air drafts. These factors depend on plant conditions and must be learned and taken into account by the operator. In general, the blanch should be adjusted

until the flesh of pieces examined immediately after blanching appears to be cooked a little more than two-thirds through. Some additional heat penetration takes place in the stack (stack blanching), because of the slow rate of cooling, and this completes the process. A more complete cook seems to be required for clingstone peaches, and visual observation as to the degree of blanch is very difficult. When dehydrated, underblanched halves retain opaque light yellow areas.

Control of the blanching process can be understood more readily if the rate of heat penetration into different parts of a cut fruit half are studied by thermocouple temperature measurements. If a peach half, for example, is exposed to steam at atmospheric pressure, the surface temperature raises at once very rapidly and then gradually approaches the steam temperature. The center of the piece does not change in temperature at first, but soon begins to raise slowly and then rapidly, approaching the surface temperature. Small fruits heat through more quickly, but about 11 minutes are required to heat the centers of large peaches and 16 minutes for pears. Although steam is distributed readily in batch blanchers, the initial steam rate must be extremely high if the fruit is to be heated quickly and uniformly. A similar condition will occur in continuous blanchers if the steam supply is not sufficient to maintain temperature in the first section of the blancher, where the cold fruit enters.

When the trays are removed from the blanchers, the surface of the fruit begins to drop in temperature almost at once, but the center of the fruit cools more slowly.

If the stack of fruit is confined so that heat cannot escape readily, the fruit cools more slowly, and the surface of the fruit at the middle of the stack remains at a high temperature and tends to overblanch. When large trays are used, artificial cooling is advisable. Bleeding losses during the blanching operation are negligible for apricots and freestone peaches, but may amount to about 6 percent of the weight of the fresh fruit in the case of peeled clingstone peaches. Details concerning the production of dehydrated blanched fruits are given in papers by Phaff, Perry and Mrak (1945); Phaff, Marsh, Mrak and Fisher (1945); and Phaff, Mrak, Perry and Fisher (1945).

SULFURING

All cut fruits except persimmons are sulfured before drying to aid retention of general quality, especially a light color. The most widely employed procedure involves exposing the cut fruit on trays to the fumes of burning sulfur in a closed and tightly sealed cabinet, Long, Mrak and Fisher (1940). Apples are frequently sulfured in continuous sulfuring tunnels containing the fumes of burning sulfur or by submersion in a bisulfite bath. A recent trend has been to drop peeled and cored apples from the peeling machine directly into a 0.1 percent solution of sodium bisulfite. This prevents core browning before slicing and sulfuring.

Absorption and retention of sulfur dioxide is conditioned by a number of factors which have been discussed by Long, Mrak and Fisher (1940); Fisher, Mrak and Long (1942); and Phaff (1945). Immature fruit absorbs SO_2 rapidly, but retains it more poorly than fully mature fruit. As an example, immature Tilton apricots absorbed 3810 parts per million of SO_2 and retained but 210, whereas fully mature fruit absorbed 3380 and retained 610. Absorption by whole fruits such as grapes or whole apricots is slow unless the skins are checked. There is also an apparent difference between similar fruits grown in different areas. An increased temperature during sulfuring tends to decrease absorption but greatly enhances retention during drying, see Table 7. The concentration of SO_2 gas in the sulfuring chamber and the period of exposure are also important factors. The burning characteristics of sulfur and the conditions under which it is burned affect the concentration and

temperature in the sulfuring house. In this connection Bisson, Allinger and Young (1942) have made the interesting observation that the presence of a few parts per million of carbonaceous material (particularly oil) greatly impairs the burning quality of the sulfur and considerable amounts of slag accumulate. Rapid drying after sulfuring is conducive to a high retention. In line with this the loss of SO_2 during drying may be unduly heavy if poor dehydration practices are used. This is particularly true if the relative humidity at the wet end of a counter flow tunnel drier is permitted to exceed approximately 65 percent. High humidities are caused by too rapid loading of the tunnel.

TABLE 7

Absorption and Retention of SO_2 by Tilton Apricots

(Sulfuring period 2 hours)

Temperature during sulfuring	SO_2 absorbed during sulfuring (parts per million in fresh fruit)	SO_2 retained after drying (parts per million in dried fruit)
66	4390	2270
93	3360	2860
122	3150	4140

Sulfuring blanched fruits requires more care than when unblanched fruits are being treated. For example, the cars containing freshly blanched fruit must cool to an approximately lukewarm condition, otherwise the SO_2 absorption may be very poor and breakdown of the fruit tissue is considerable, especially in the case of the soft fruits such as apricots and freestone peaches. When a continuous blancher is used, some cooling takes place while the trays are loaded on the car, but additional cooling is advisable. Cars leaving a cabinet blancher are hot throughout. Cooling may be effected by placing the cars in a draft or by putting them in a tunnel dehydrator with or without heat. (The latter is more efficient, particularly when a cabinet blancher is used.) Evaporative cooling in a dehydrator under these conditions is considerable so the use of heat to dry the outer surface is advisable. This eliminates bleeding in the sulfur house and tends to result in an increased absorption of SO_2. For predrying as indicated above it is desirable to place the cars of freshly blanched fruit in the hot end of a parallel-flow tunnel dehydrator. To have a satisfactory evaporation rate, the inlet air must be 180 to 190° F., and have a large wet-bulb depression. The temperature drop is great and only a small number of cars may be in the tunnel at one time. Since blanching causes an inactivation of enzymes causing browning, and results in an increased drying rate, the fruit will lose its moisture rapidly without discoloration. Likewise there is no loss in vitamin C during this predrying step. In using this new procedure it is advisable to use little or no circulation and to regulate the number of cars per tunnel so the dry bulb temperature at the cool end of the tunnel is still 15 degrees F. higher than the wet-bulb temperature. If the periodicity of introducing and removing cars is 15 minutes or less the hot end air temperature may be as high as 200° F. without danger of scorching the fruit. When the predried fruit is removed it is placed in a sulfuring chamber and sulfured in the usual manner.

At present, the only practical way to sulfur fruit is by exposing the halves to the fumes of burning sulfur. The use of sulfite solutions is impractical because of poor penetration and leaching of sugar. The use of liquid compressed sulfur dioxide in cylinders requires the presence of a fan in each sulfur house, because SO_2 is a gas of high density and tends to collect at the bottom of the house. It also requires exceptionally tight sulfur houses, more supervision and is more expensive.

Almost all commercial sulfuring houses are provided with vents to promote the burning of sulfur by allowing a more generous supply of oxygen to the burner. The result is improved burning, but large amounts of SO_2 vapors escape in and around dried fruit plants. Also a great excess of sulfur over the theoretical amount must undergo combustion to insure proper SO_2 uptake by the fruit. Recently Stead, Taylor and Phaff (1946) have re-tested and expanded the so-called "dense smoke" method of Hiltner (1928, unpublished data) consisting of burning much smaller quantities of sulfur in a completely tight chamber. In spite of Hiltner's original difficulties the method seems promising and workable. It would have the great advantage of reducing health hazards to plant personnel of continuous exposure to SO_2 vapors.

DEHYDRATION

In the manufacture of dehydrated cut fruits, the product, after sulfuring, is dried to completion in a countercurrent tunnel dehydrator. The higher the air flow and the higher the finishing temperature, the more cars a tunnel can hold without exceeding the maximum allowable humidity at the cool end. The rate of air flow should be from 600 to 1,000 linear feet per minute. Observations by Stadtman, *et al.* (1946) have shown that the finishing temperature may be as high as 160° F. if the fruit is not dried to a moisture content lower than 25 percent. The finishing temperature should be lowered to 145° or 150° F., respectively, if 17 or 20 percent moisture is required. Heat damage becomes greater as the moisture content becomes lower. Not only is the fruit in the dehydrator longer, but the flesh temperature of the fruit during the final stage of drying approaches that of the drying air. Also, the concentration of the reacting substances causing biochemical deterioration becomes greater.

A convenient rule for humidity control on the wet end of a countercurrent tunnel is to allow a minimum wet-bulb depression of 15° F. The average temperature drop for a tunnel properly loaded with peeled, blanched clingstone peaches is about 97.5° F. per double car of fruit (6 feet) at an air flow of about 900 linear feet per minute.

Prior to the work of Moses (1942), Guillou (1942) and Perry (1944) the calculation of prune dehydrator design was based on the assumption of tunnel dimensions, temperature and humidities in accord with good practice. The drying times were estimated from experience with comparable installations. A heat balance was then used to calculate air circulation necessary to maintain the assumed humidity. Heat losses in air discharge and through the walls was also calculated and added to the heat used in evaporation in order to obtain furnace load. Such a design procedure was followed by Christie and Ridley (1923) who were active in the early development of the dehydration industry in California. Measurements of drying rates of prunes were made by Moses (1942) and Guillou (1942) to determine the quantitative relations between dehydrator conditions, drying rates and quality of the product. They developed optimum values for each of the controllable variability and embodied them into a design of closest practicable approach. The design developed is for a direct heat cross flow prune dehydrator (Guillou and Moses, 1943). This is the first time to our knowledge a fruit dehydrator has been designed on laboratory data concerning the drying characteristics of a particular fruit.

Perry (1944) has studied heat and vapor transfer in the dehydration of prunes. Drying rate of prunes was found to be proportional to the free moisture ratio in the usual drying range (down to 0.2 pounds of moisture per pound of dry matter). It decreases for the lower moisture contents because of the decrease in moisture conductivity of prune flesh. Changes in air-stream relative humidity do not appreciably influence drying rates of prunes if the relative humidity is less than 35 percent,

because the equilibrium moisture content-relative humidity curve does not rise rapidly until relative humidities over 50 percent are reached. The principles involved in the dehydration of fruits have been discussed by Mrak, Perry, Phaff, Marsh and Fisher (1946).

Data on the survival of yeasts and molds on prunes during handling and dehydration have been reported by Phaff, *et al.* (1946). Although living yeast and molds are present on prunes at the start of the dehydration period they are killed during drying. See Table 8. Recontamination may be minimized during subsequent grading and storage if good plant sanitation practices are followed.

TABLE 8

Effect of Dehydration Practices on the Yeasts Present in Prunes

(Number of yeasts per 20 prunes)

	Plant A	Plant B
Fresh prunes		
Sample 1 (Farm 1)	2×10^5	1×10^5
Sample 1 (Farm 2)	1.4×10^4	8×10^3
From trays after washing, before dehydration		
Sample 1	1.3×10^6	8.5×10^5
Sample 2	1.1×10^5	
From trays at start of dehydration (cool end of tunnel)	8×10^6	
From trays at end of dehydration (hot end of tunnel)	0	0
Stored prunes in bins	0	1.2×10^3

A new development in the dehydration of fruits is the use of vacuum driers to reduce the moisture content of commercial dried fruit to less than 2 percent for the purpose of making fruit powders and "nuggets." Large tonnages of apple nuggets were produced during the war for use by the armed forces. They offer the advantage of superior storage qualities, and ease of reconstitution with good retention of flavor. Dried apples are merely ground and dried in vacuum although a puffing process is sometimes used. This involves releasing the vacuum about midway in the process, introducing steam under pressure, releasing the steam pressure and completing dehydration under vacuum.

An interesting procedure that has not gone beyond the experimental stage involves the use of oxygen-free flue gases from which moisture and foreign materials are first removed. The CO content of the flue gases is sufficiently high according to the inventor to prevent deteriorative processes during preparation and drying.

Electronic heating procedures are receiving much publicity and some amazing statements are being made although, so far as the authors are aware, no one has yet demonstrated the feasibility of electronic drying for fruits.

DRYING RATIO

Maturity, area of production, variety, pretreatment waste, season, and drying conditions have been shown to be important factors influencing drying ratio. (Pitman, Nichols and Mrak (1934); Jacobs, 1942 and 1944; and Phaff, *et al.* 1945 III). Factors influencing the drying ratio of prunes and grapes were discussed previously under harvesting. With respect to clingstone peaches the overall drying ratio depends on the total solids content, the preparation losses and to a great extent the percentage of sort-outs in the fresh and finished product. In cannery-grade fruit, an allowance of 6 percent defective fruit is usually made. In orchard-run fruit, the

percentage may be considerably higher. Although the drying ratio of the flesh itself ranges from 5 or 6 to 1, the overall drying ratio of No. 1 fruit frequently is slightly more than 9 to 1.

It is possible to test the solids content of the fresh fruit with a refractometer. In this way one can orient himself about the flesh drying ratio and determine whether too immature fruit is being delivered. There is a fairly constant ratio between soluble solids as determined by the refractometer and total solids as determined by a vacuum oven. The average numerical value of this ratio was found to be 1.086. In other words, if the soluble-solids content expressed as sucrose (found by means of the refractometer) is multiplied by 1.086, total solids content is obtained. The drying ratio equals S_2/S_1, in which S_2 is the solids content of the dried product and S_1 the solids content of the fresh product. Assuming that the product is to be dried to a moisture content of 25 percent, the universal value of S_2 is 75. After determining the value of S_1 as described above, the drying ratio can be calculated. The overall drying ratio equals $\frac{S_2}{S_1 \times a}$, in which a represents the fraction of the fruit recovered after preparation. For instance, if sorting, pitting and peeling removes 35 percent of the fruit, the recovery is 65 percent and $a = 0.65$. This value is a reasonable figure for good quality peaches, pitted and peeled according to good commercial practice.

STORAGE DETERIORATION

Dried fruits undergo a chemical deterioration in storage. In recent studies on the storage of dried apricots, Stadtman, *et al.* (1946 a,b,c.) after working out quantitative colorimetric methods for following the deterioration of dried apricots, determined the influence of moisture, sulfur dioxide and oxygen on the rate of deterioration under carefully defined conditions.

They showed that oxygen, moisture content and sulfur dioxide content all have a considerable influence on storage quality, and their action may be antagonistic under certain conditions. The "edible life" of apricots is directly proportional to the initial SO_2 level over the range of 1500-8000 p.p.m. and is approximately doubled by increasing the sulfur dioxide level from 2000-7000 p.p.m. A very interesting finding is that fruit reaches the inedible state after about 65 percent of the initial sulfur dioxide is lost, and it is possible therefore for fruit to darken even though the the sulfur dioxide content is still high. Thus SO_2 retards deterioration, but cannot prevent it. Oxygen increases the rate of darkening. This detrimental effect is due in part to a lowering of the sulfur dioxide level by conversion of the latter to sulfate. The greatest part of the oxygen damage, however, takes place in an unknown way. The fruit takes up oxygen and produces carbon dioxide in a non-enzymatic manner. The rate of oxygen uptake is entirely independent of sulfur dioxide concentration but decreases on lowering the moisture content, being about one-tenth at 5 percent moisture of what it is at 24 percent. A low moisture content thus seems to offer advantages for storage in air. Their studies on the effect of moisture apart from the influence of oxygen have shown that the rate of deterioration of apricots stored at 120° F. decreases almost linearly with increasing moisture content over the range of 10 to 32 percent moisture, Table 9. The maximum rate of deterioration occurs at 5-8 percent moisture. If the moisture level is reduced to one percent or below the storage qualities are far superior to that of fruit with a higher moisture content providing drying can be accomplished without causing heat damage. The rate of darkening was found to double approximately with every 10° F. rise in temperature. The evidence obtained indicates therefore the desirability of packing apricots at a

high moisture content (about 25 percent), high SO_2 level in a tight pack (low oxygen-fruit ratio) in air tight container.

The research department of the Continental Can Company (1944) and Heberlein, *et al.* (1944) compared the storage qualities of apple nuggets and of dried cranberries packed under various conditions. Products packed in gases other than oxygen were found to be superior to those packed in air. However, so far as color, ascorbic acid, thiamine and riboflavin content are concerned there was little difference between air and gas packed samples.

TABLE 9

Effect of Increasing Moisture Content on Edible Life of Apricots at Various SO_2 Levels—Percent Increase in Storage Life by Increasing Moisture Content from 10-24%

(47 ml. of oxygen per 100 grams, lot 2)

Initial SO_2 p.p.m.	SO_2, dry basis		SO_2, wet basis	
	49° C.	36.7° C.	49° C.	36.7° C.
1000	36.0	.....	38.5	.....
2000	35.5	.....	50.8	.....
3000	40.0	10.4	66.7	19.6
4000	40.3	9.9	68.8	20.2
5000	40.6	9.6	71.8	20.8
6000	40.0	10.0	74.5	23.0
7000	42.0	10.4	77.2	24.0

The spoilage of dried prunes, figs and dates has been a serious problem. In order to prevent mold and yeast spoilage it has been customary to pasteurize as described by Clague and Fellers (1933), pack with a low moisture content, or hold the fruit in cold storage in line with the conditions outlined by Barger (1941 a and b). Pasteurization is objectionable in that it causes heat damage and changes the flavor of the fruit. When moisture is held at a low level such as 23 percent in figs the fruit does not have the desired acceptance. Furthermore, there is a tendency for the fruit sugar to crystallize on the surface. The use of cold storage is costly and not always possible. Whelton, *et al.* (1946 a and b) have described a procedure whereby the fruit may be sterilized by applying small quantities of ethylene oxide or propylene oxide to the open package and then sealing it. This procedure offers promise for figs and dates and prunes since it will enable the retailing of dried fruits with a higher moisture content and hence greater acceptance.

Spoilage by insects is a serious problem that has received a great deal of attention. The problem of insect control is not as serious as it was a few years ago because of the introduction of methyl bromide gas as a bin and chamber fumigant and the liquid packing fumigants, isopropyl formate and ethyl formate. (Fisher, 1945). About one pound of methyl bromide is used in a thousand cubic feet of space in a tight chamber. When line fumigants are used, about .5 ml. are added to each twenty-five pound box of fruit.

At present considerable attention is being directed to factors involved in plant sanitation. A concerted effort is being made to eliminate rodents and insects and to minimize the possibilities of microbiological contamination.

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BASIC THEORY AND LIMITATIONS OF HIGH FREQUENCY HEATING EQUIPMENT[1]

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Radio frequency heating, sometimes referred to as electronic or high frequency heating, is the new heating method which is revolutionizing processes in all industries. Its use in the food industry is just beginning to be realized. Many misconstrued ideas of its possibilities have received publicity and it therefore remains for the food technologist and electronic engineer to apply this new heating means to the many food processes where its many advantages can be fully and properly realized.

Because radio frequency heating requires equipment and techniques previously used only by radio engineers, there is the need for extensive education before it can be intelligently applied in the largest of all industries, the food industry. It is with this thought in mind that the following discussion on the theory of radio frequency heating is given to assist the food technologist in the proper application of this new heating method. Research and more research will be necessary to establish the most logical and useful applications of this new heating method in the food industry.

Since man first discovered fire we have been obliged to heat a substance by placing that substance near or in contact with another substance which is at a higher temperature and then sit back and wait for the transfer of heat energy from the hot body to the colder one. With radio frequency heating we have a means of generating heat directly in the material to be heated and at speeds limited only by the character of the material. This form of heating, with its phenomenal speed and other distinctive advantages, causes us to completely change our whole conception of heating problems.

Let us first consider the basic application of heat to a material regardless of where that heat may come from.

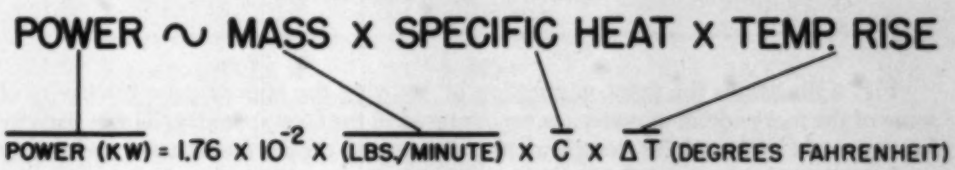

FIG. 1.

Fig. 1 shows the basic formula for determining the amount of power that is used to heat any given amount of material. We see that power varies with the mass or amount of material, the specific heat of the material and the temperature rise that we desire. Accurate analysis often requires taking such factors as radiation, conduction and convection losses into account and can be arrived at by conventional means.

INDUCTION OR DIELECTRIC HEATING

In obtaining the necessary power by electronics, or more specifically by radio frequency energy, we have a choice of two basic methods of heating. These are known as induction heating and dielectric heating. Induction heating is briefly

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defined as the generation of heat in a material normally considered an electrical conductor when that material is placed in a varying magnetic field. Dielectric heating is the generation of heat in a material normally considered as an electrical insulator when that material is placed in a varying electrostatic field. In the food industry there is a possible need for both induction and dielectric heating, and therefore we will attempt to show the possible uses of both types.

Because the basic difference between induction and dielectric heating depends upon whether the material is an electrical conductor or nonconductor, one convenient method of determining which type of heating should be used on a particular material can be had by studying the resistivity of that material. Resistivity is the electrical terminology for describing the ability of a material to carry electric current.

RESISTIVITY
AS
GUIDE TO SELECTION OF TYPE OF HEATING

MATERIAL OR PRODUCT	RESISTIVITY OHM/CC	
COPPER	1.7×10^{-6}	INDUCTION HEAT
HAM	75	
APPROXIMATELY 100 TO 1000 OHM/CC		
TAP WATER	5000 TO 10,000	DIELECTRIC HEAT
POTATOES	5000	
CARROTS	11,000	
BREAD	30,000	
FROZEN PEAS	50×10^6 (COMPLETELY FROZEN) TO 125,000 (PARTLY DE-FROSTED)	

FIG. 2.

Fig. 2 illustrates the point in question by showing the approximate resistivity of some of the more common materials encountered in the food industry. The resistivity for copper is indicated for comparative purposes, as copper is the most commonly used metal for conducting electricity because of its low resistivity (1.7×10^{-6} ohms/cubic centimeter). On the other hand, ham has an approximate resistivity of 75. Such materials as water, potato, carrots, bread and frozen products have a resistivity varying from approximately 5000 to 50,000,000 ohms per centimeter. Generally speaking, those materials with a resistivity below the 100 to 1000 ohm region can be heated by induction heating and those materials above 1000 ohms can be heated by dielectric heating. This dividing line is not critical and is merely a rough guide to indicating the approximate transfer point between induction and dielectric heating.

INDUCTION HEATING

Let us first consider induction heating by studying Fig. 3, which shows a metal gear suspended within an inductor coil.

If alternating current power is passed through this coil, an electromagnetic field is set up within that coil which in turn induces current to flow around the outside

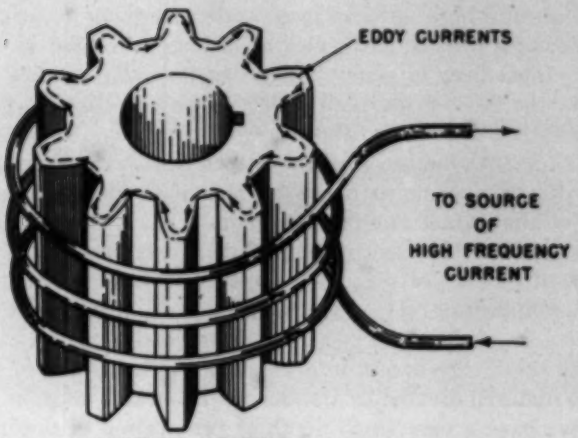

FIG. 3.

$$\text{DEPTH PENETRATION} \sim \sqrt{\frac{\text{RESISTIVITY}}{\text{FREQUENCY}}}$$

FREQUENCY	COPPER RESISTIVITY (1.7 MICROHMS/CC)	HAM RESISTIVITY (APPROX.) (75×10^6 MICROHMS/CC)
60 CYCLES	$\frac{1}{3}$ INCH	188 FT.
1×10^6 CYCLES (1 MEGACYCLE)	$\frac{26}{1000}$ INCH	5 INCH
100×10^6 CYCLES (100 MEGACYCLES)	$\frac{26}{10,000}$ INCH	$\frac{1}{2}$ INCH
500×10^6 CYCLES (500 MEGACYCLES)	$\frac{12}{10,000}$ INCH	$\frac{1}{4}$ INCH

FOR EFFICIENT HEATING DEPTH OF PENETRATION SHOULD BE LESS THAN $\frac{1}{3}$ THE THICKNESS OR DIAMETER

FIG. 4.

surface of the gear. These currents, due to a phenomenon known as skin effect, flow only in a layer very near the surface of the gear or material being heated. These currents are of a high order of magnitude and generate heat at the surface of the material in exactly the same manner as heat is generated in the wires of your electric toaster. This heat is generated the instant the magnetic field is created inside the coil by the flow of alternating electric current through that coil. The fact that these currents are induced in the material gives rise to the name of induction heating. It is not within the scope of this paper to cover thoroughly the subject of skin effect but it is sufficient to point out that skin effect is proportional to the frequency of the alternating current power used. The higher the frequency the closer the current is forced to the surface of the material.

Fig. 4 shows the effect of this phenomenon on the selection of the proper frequency for induction heating. Here again we have a comparison between copper and the food product ham. Skin effect is commonly defined by depth of penetration. The depth of penetration of the current into the material varies as the square root of the resistivity of the material divided by frequency. From this relation we see that in the case of copper we have a very small depth of penetration of the induced current as compared with a piece of ham. To produce efficient heating in a material by induction it is necessary that this depth of penetration of the induced current be less than one-third the thickness or diameter of the material being heated. From Fig. 4 it can easily be seen that it would be impossible to heat a whole ham at 60 cycles, but if we reach a frequency somewhere between 1,000,000 cycles (1 megacycle) and 100,000,000 cycles (100 megacycles) it becomes practical to heat the ham by induction heating. A frankfurter which has approximately the same resistivity as ham, has a diameter of about ¾ to 1 inch, and therefore, to do an efficient heating job by induction heating a frequency somewhere in the neighborhood of 200 megacycles (MC) would be desirable. Similarly, the depth of penetration can be used as a guide to the proper frequency to heat other types of materials providing the resistivity of that material is known.

DIELECTRIC HEATING

Next let us consider dielectric heating. It is this form of heating which will find more widespread use in the food industry. As defined briefly, dielectric heating is the placing of a nonconducting material in an alternating electrostatic field. This is accomplished as shown in Fig. 5-A by placing the material between two plates so that the whole represents an electrical capacitor made up of the two electrodes and the insulating material between. In electrical terms this insulating material is known as the dielectric of the capacitor and therefore the terminology "dielectric heating." Basically, in induction heating we place the material in a coil and in dielectric heating we place the material between two plates of a capacitor.

Fig. 5-B illustrates possible molecular structure of a dielectric material, and if we place an alternating voltage across the two electrodes, one electrode assumes a positive charge and the other a negative charge at any given instant and the electrostatic field between these two plates causes a deformation of the molecular structure in the material. Particles making up the molecular structure contain electric charges and therefore they have an electrical force exerted upon them by the electric field. If we reverse the polarity on the two plates (Fig. 5-C) by the action of the alternating voltage, the molecular structure is then deformed in the opposite direction. The result is molecular stress or molecular friction in the material. Now it can readily be seen that as the charge on the plates is alternately reversed first in one direction and then the other the effect of molecular friction is increased and appears

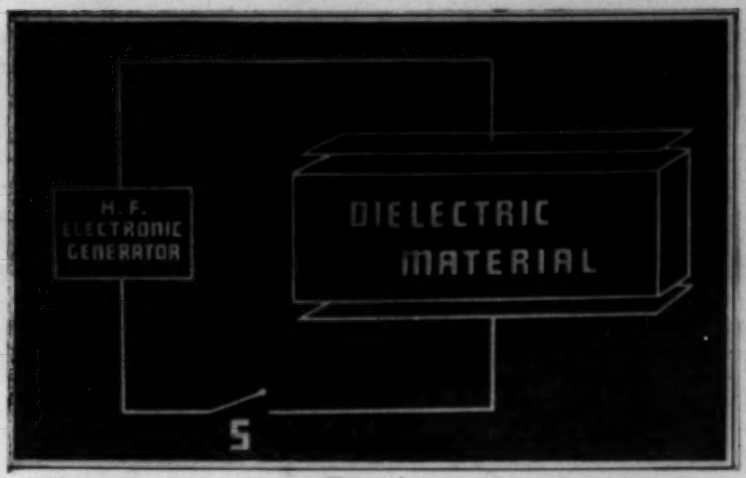

FIG. 5-A

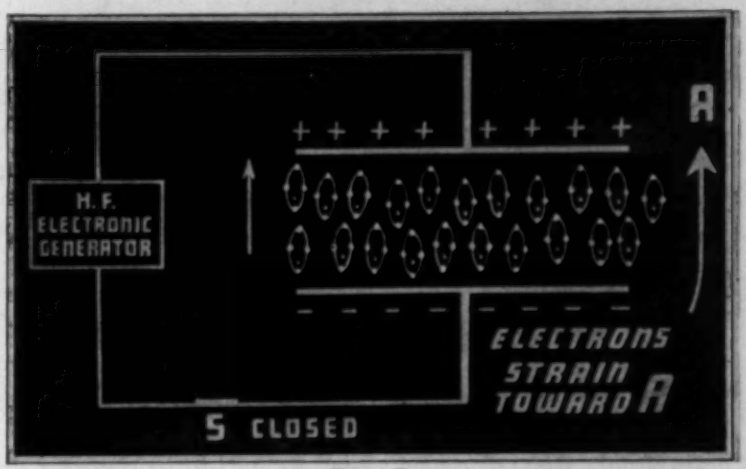

FIG. 5-B

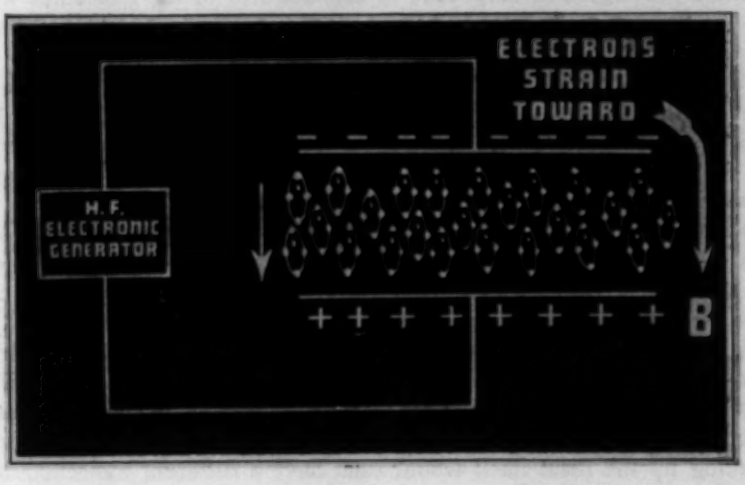

FIG. 5-C

in the form of heat generated uniformly throughout the material. It is this feature of dielectric heating to produce heat uniformly throughout a material that gives it many of its advantages.

To further illustrate the action which takes place within a material, let us take a look at the fundamental relation for generating power in a material by dielectric heating. Fig. 6 shows that this fundamental relation for power density necessary to produce a desired heating effect varies with the frequency being applied and varies as the square of the voltage being applied, and it varies as a factor known as "loss factor" of the material. First let us consider the effect of frequency. By enlarging a section of the material we see that the molecules are shaken or distorted at a rate directly dependent upon the frequency used. In other words, frequency determines the speed of molecular agitation.

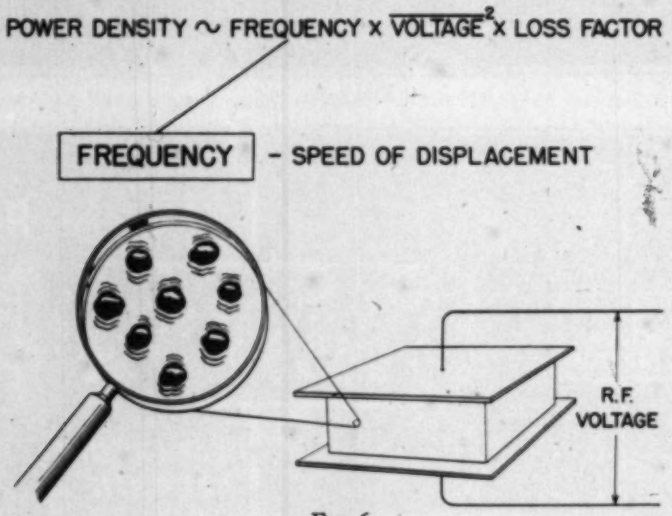

FIG. 6.

Fig. 7 illustrates the effect of voltage. Here we see that by changing the voltage we determine the degree or amplitude of displacement of the molecules within the material. As the voltage is increased the amplitude of displacement becomes rapidly larger.

Fig. 8 illustrates the effect of loss factor which is essentially the friction co-efficient of the molecular structure of the material. Some materials will have a higher friction coefficient than other materials due to the molecular structure of that material. As loss factor (friction coefficients) increases, the rate of producing heat is increased.

From this discussion we can generally conclude that: first, it is desirable to use as high a frequency as possible; second, it is desirable to use a voltage as high as possible, and that these actions become increasingly necessary to produce rapid heating as the "loss factor" of the material becomes lower and lower.

The fundamental relation for power, Fig. 8, also gives us the reason for unequal heating noted in nonhomogeneous materials. As a classic example it can be readily understood that if we should attempt to dielectrically heat a T-bone steak, each of the various parts of that steak such as the bone, the fat, and even the various fibers making up the meat itself would each have a different molecular structure, and therefore a different "loss factor." This condition actually exists and the

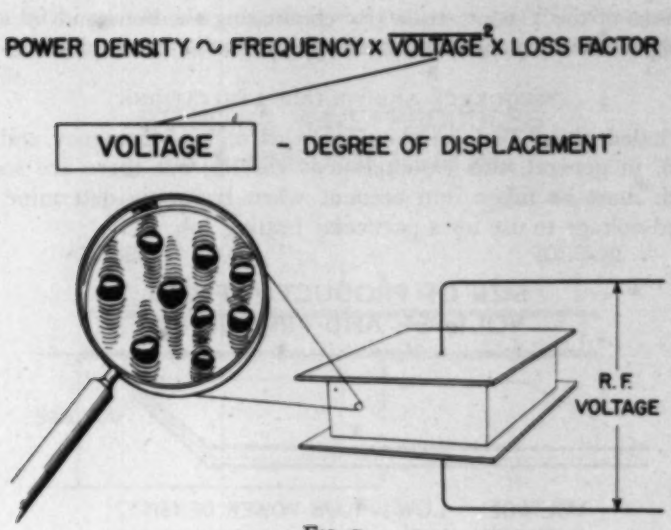
POWER DENSITY ~ FREQUENCY x VOLTAGE² x LOSS FACTOR
VOLTAGE
- DEGREE OF DISPLACEMENT
R.F. VOLTAGE

FIG. 7.

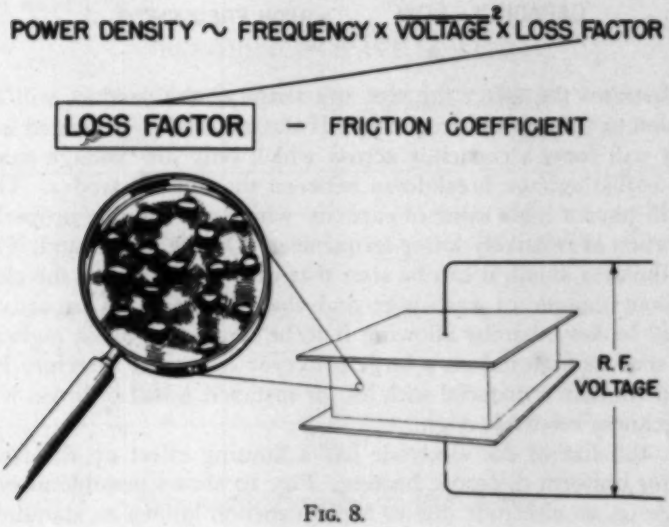
POWER DENSITY ~ FREQUENCY x VOLTAGE² x LOSS FACTOR
LOSS FACTOR
- FRICTION COEFFICIENT
R.F. VOLTAGE

FIG. 8.

difference in "loss factor" is so great from bone to fat to meat fiber that the heating rate of each is radically different. The result is extreme uneven heating of the various portions of the T-bone steak. By eliminating the bone and fat a reasonable job of cooking the meat by dielectric heating can then be accomplished.

FREQUENCY AND VOLTAGE LIMITATIONS

We concluded above that we should use as high a frequency and voltage as possible, and, in general, this assumption is correct, but there are some limiting factors which must be taken into account when trying to determine the proper frequency and voltage to use for a particular heating job.

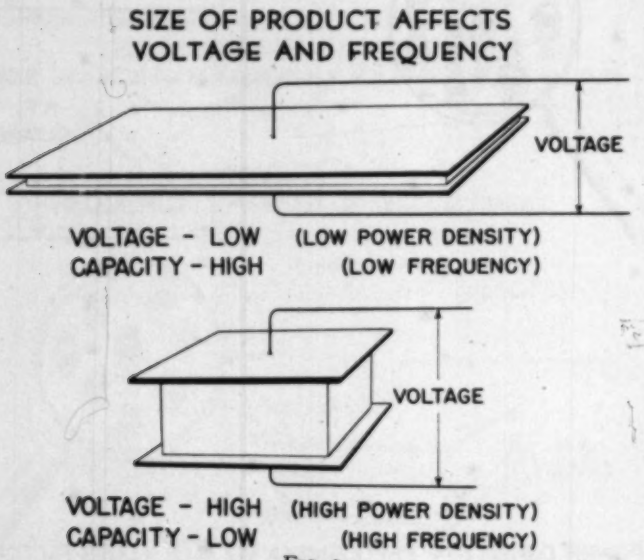

FIG. 9.

Fig. 9 illustrates the effect the size and shape of the product will have on the proper selection of voltage and frequency. If the material to be heated is thin and of large area, it will form a capacitor across which only low voltage can be applied because of possible voltage breakdown between the two electrodes. The capacitor so formed will have a high value of capacity which can only be properly tuned for efficient operation at relatively lower frequencies. On the other hand, if the material is thick and the area small, it can be seen that the voltage across the electrodes can be high without danger of flash-over and that the value of capacity of such a condenser will be low, thereby allowing it to be tuned to a much higher frequency. Large areas such as material on a large conveyor belt must therefore be heated by lower frequencies than a material such as, for instance, a loaf of bread whose area is small and thickness relatively high.

Similarly, the size of the electrode has a limiting effect on the frequency that can be used for uniform dielectric heating. Fig. 10 shows possible uneven distribution of voltage on an electrode due to a phenomenon known as standing waves. If the length of the electrodes becomes large in comparison to the wave length of the frequency being used, possible unequal voltage distribution as shown in Fig. 10 will exist. This unequal distribution of voltage results in an unequal distribution of heat in the material between the electrodes. For certain heating problems this is definitely

undesirable; however, in some cases this phenomenon can be put to useful practice. In general, it can be said that the electrodes must be made smaller and smaller as the frequency is raised. As frequencies in the region of 200 MC are approached, the electrodes become rather small and conventional tuning means begin to reach their practical limit.

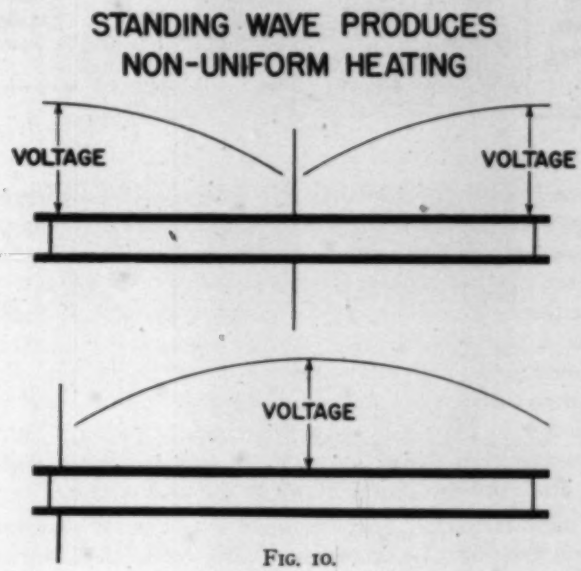

FIG. 10.

A convenient guide to proper electrode size for practical uniform heating is to keep the electrode length, as measured from the point of power application, to not over 1/16 wave length. Fig. 11 gives ready reference for rapid conversion from frequency to wave length.

FREQUENCY - WAVE LENGTH

$$\text{Wave length (meters)} = \frac{300}{\text{Frequency in MC.}}$$

Frequency MC	Wave length meters
2	150
3	100
4	75
5	60
10	30
15	20
20	15
30	10
50	6
100	3

FIG. 11.

THE RADIO FREQUENCY GENERATOR

The generation of the radio frequency energy which is used for either induction or dielectric heating is performed by what is known as a radio frequency generator or oscillator. Fig. 12 illustrates the essential parts of such a radio frequency generator.

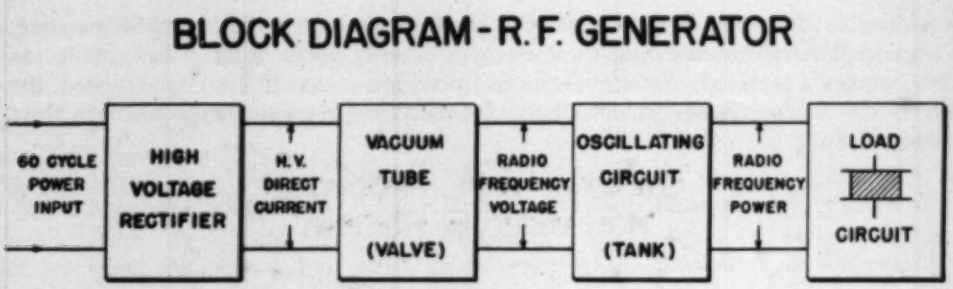

FIG. 12.

Power is taken from the regular power source and is transformed and rectified by a high voltage rectifier into high voltage direct current. This power is applied to the radio or vacuum tube. The vacuum tube acts as a means of transferring the high voltage direct current power to an oscillating circuit at a radio frequency voltage. The oscillating circuit is normally composed of inductance and capacity, commonly termed a tank circuit by electronic engineers, and determines the frequency of the generator. This oscillating circuit stores energy obtained from the direct current source through the medium of the vacuum tube and supplies it to the dielectric load circuit in the form of radio frequency power. Tuning systems are quite often necessary in the load circuit to insure efficient transfer of the radio frequency power from the oscillating circuit to the load circuit.

Various size radio frequency generators are available for performing both induction and dielectric heating. In accordance with National Electrical Manufacture Association standards, the ratings of these generators range from 1 KW through 2, 5, 10, 20, 50, 100 and 200 KW sizes. In general, frequencies are now available commercially up to 30 MC and in special types of equipment up to approximately 200 MC at low power levels. Above 200 MC, heretofore secret military developments, will have to be turned into commercial products. Development along this line is well into the future with the major portion of the work placed on electronic tube engineers.

Fig. 13 illustrates the general appearance and construction of the smaller size generators up to and including 10 KW for dielectric heating. Usually the smaller sizes up through 10 KW, and in some cases 20 KW, are portable in nature. They are mounted on casters and are self-contained in that they include all equipment and tuning circuits necessary for performing dielectric heating between electrodes which are a part of the equipment and located in the upper cage structure. The construction is usually such that the power and rectifier circuits are located in the lower section of the generator, while the vacuum tube and associate radio frequency circuit elements are located in the upper portion of the unit in close proximity to the load electrodes at the top.

Fig. 14 indicates the general construction of a large unit of 100 KW rating, suitable for dielectric heating at a frequency of 13.66 MC. The use of generators of the 50, 100 and 200 KW size normally requires the heating to take place at some distance remote from the generator. Transmission lines and tuning equipment at the work position are usually necessary as accessories.

ECONOMY OF R. F. HEATING

During the 1930's considerable work was done in the laboratory in an attempt to apply radio frequency energy to various industrial problems. Included among

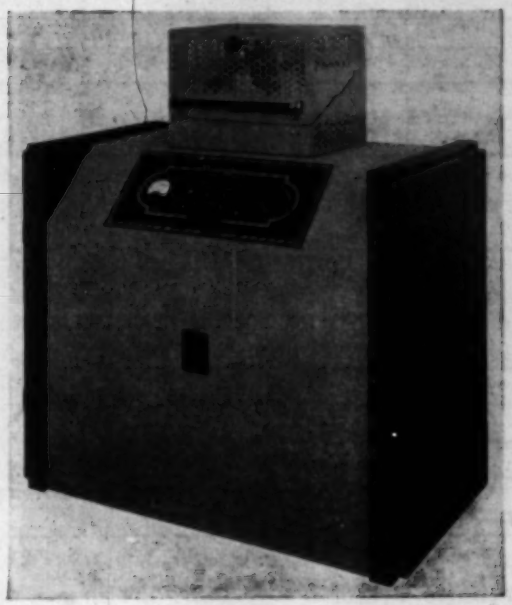

FIG. 13.

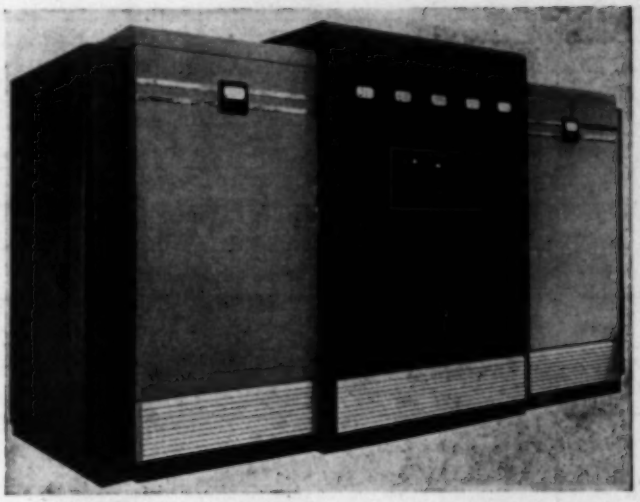

FIG. 14.

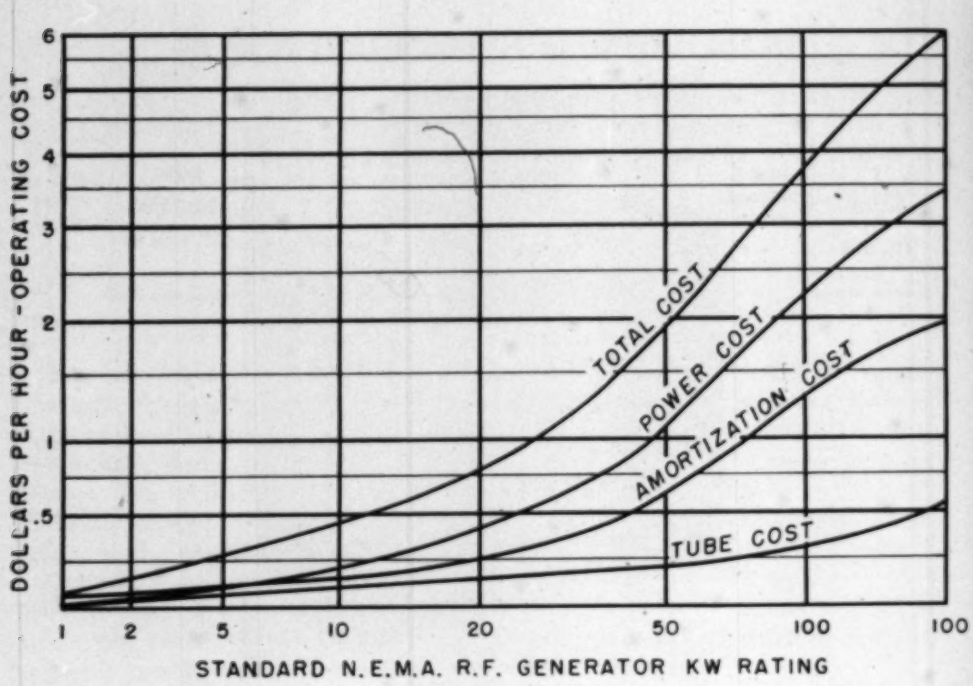
DOLLARS PER HOUR - OPERATING COST
6
5
4
3
2
1
.5
TOTAL COST
POWER COST
AMORTIZATION COST
TUBE COST
1
2
5
10
20
50
100
100
STANDARD N.E.M.A. R.F. GENERATOR KW RATING

FIG. 15.

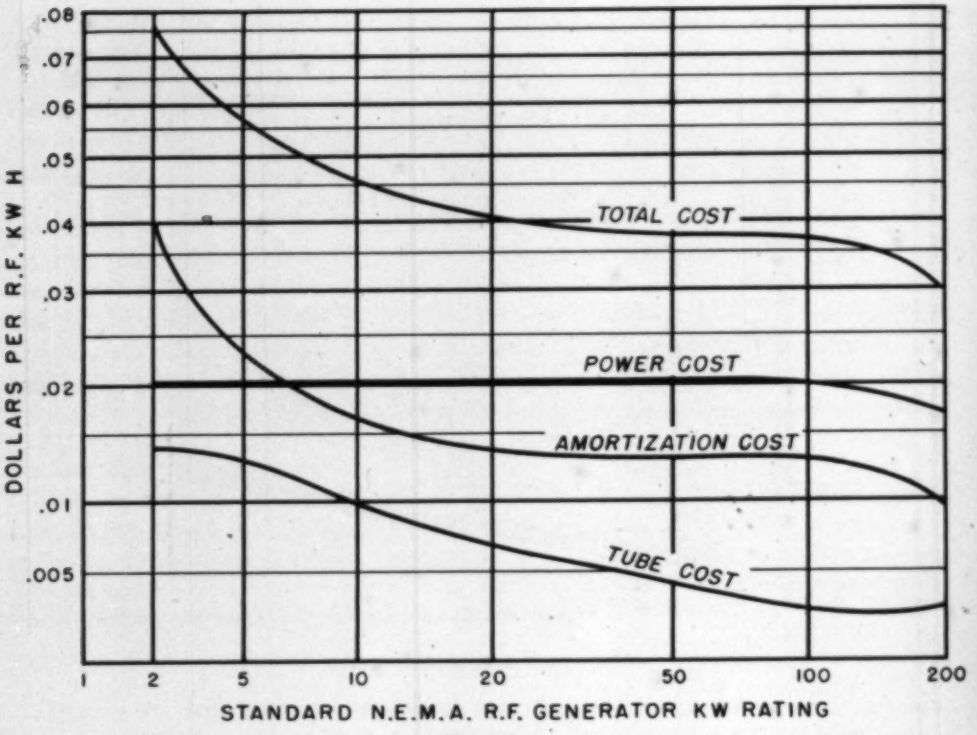
DOLLARS PER R.F. KW H
.08
.07
.06
.05
.04
.03
.02
.01
.005
TOTAL COST
POWER COST
AMORTIZATION COST
TUBE COST
1
2
5
10
20
50
100
200
STANDARD N.E.M.A. R.F. GENERATOR KW RATING

FIG. 16.

these were a number of developments in the food industry. Most notable of these developments was the use of power at approximately 40 MC for the sterilization of grain and other similar products. At that time it was very definitely demonstrated that larvae and their eggs could be permanently destroyed by the use of high frequency energy. Sterilization of chocolate products normally contaminated by the moth associated with the cocoa bean was also very conclusively demonstrated. The problem of precooking hams was also studied and found to be possible at frequencies in the neighborhood of 6 to 10 MC. Many laboratory experiments were conducted, such as cooking of hamburgers, hot dogs, steaks, the popping of corn, roasting of peanuts, etc.

All of this work in the 1930's resulted in very few actual commercial installations, primarily because the over-all operating cost using radio frequency energy appeared to be too great. The present day acceptance of electronics plus available manufacturing facilities for quantity production has stimulated interest and has also reduced the cost of the equipment to a point where many of these applications now can be considered economically sound. To assist in studying various developments from the economic standpoint, the data shown on Figs. 15 and 16 may be helpful.

Fig. 15 gives the cost in dollars per hour for operating the various size standard radio frequency generators. The total cost is broken into three parts; namely, vacuum tube maintenance, amortization cost, and power cost. This data is based on operating the radio frequency generator full time and any estimates made from this data should be governed accordingly. Knowing the size generator, it is easy to estimate from this data the cost per piece or per pound for heating the desired product.

Fig. 16 shows the cost of radio frequency power in dollars per kilowatt for the various standard size generators. The total figure is broken into tube cost, amortization and power cost. It is interesting to note that cost per kilowatt is higher for the smaller size generators in the 2, 5 and 10 KW class than it is for the larger generators of the 50, 100 and 200 kilowatt class. This is due to the proportionate higher equipment and tube cost for the small ratings.

It is quite often advisable before entering into a large scale development progam on the use of radio frequency heating to thoroughly investigate the possible cost based on the assumption that the desired results can be obtained by the use of radio frequency energy. By assuming that the results can be obtained and making some simple calculations using data from Figs. 15 and 16, a quick indication can be obtained as to whether the development work will justify the ultimate production gains. So often high frequency heating greatly improves the quality of the product, and this improvement must in some way be evaluated in the economic study. This is probably true in the majority of the problems which will be encountered in the food industry.

In conclusion, it can be said that a vast amount of experimental work is necessary to exploit the possible uses of this new tool in the food industry. A large share of this burden of development, of necessity, will fall on the shoulders of food industry people. This is basically so because so many of these problems involve the question of quality and only those versed in the technology of the food industry can properly evaluate the gains obtained by the use of radio frequency heating.

THE TREATMENT OF PACKAGED BREAD WITH HIGH FREQUENCY HEAT[1]

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Heat is one of the basic tools of the food industry. Even in the preservation of food by freezing, it is necessary to prepare many of them by means of a heat treatment. In applying heat to materials, a major problem is how to get it to the middle of the mass. In fluids it was first accomplished by stirring the mass in an externally heated container, thereby bringing the unheated center portion to the heated outer area. Later, this process was greatly improved by heating the liquid while it was being pumped through tubes in thin layers, so that heating was speeded up and the danger of overheating lessened. But the problem of getting heat into the center of solid masses, especially in materials that were poor conductors of heat, was a challenging one. The use of high frequency, or dielectric, heating, whereby heat is generated throughout a mass simultaneously, seemed to offer a solution.

FIG. 1. Wrapped sliced white bread 14 days old. Left—heated to 140° F. by electronic heat. Right—control.

The appearance of this new method of heating attracted immediate attention. Investigators showed that it was applicable in many fields, such as the treatment of plastics and leather, and in the preparation of laminated wood. At the Institute of Food Technologists meeting in Chicago in 1944, Sherman *(1)* described his experiments in applying electronic heat to various food processes, such as cooking, dehydration and sterilization. More recently, Moyer and Stotz *(2)* pointed out the possibilities of blanching vegetables with electronic heat, thereby eliminating to a large extent the loss of nutrients encountered when steam or hot water blanching is applied.

Because of the unique properties of high frequency heating, it was thought that it might be of particular value in heating wrapped bread to render it sterile in regard to mold. Bread is an excellent medium for mold growth. Under optimum conditions, mold will develop within two or three days. As the loaves leave the oven they are sterile, having been baked at 400-450° F. Although scrupulous care may be

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taken to keep equipment clean and the bakery sanitary, contamination occurs during cooling, slicing, and wrapping.

It is important that bread that is to be heated by high frequency be wrapped in materials that will not lose their effectiveness during heating and storage. As some moisture is driven from the bread during heating, the wrapper must prevent its escape or the bread will be too dry. If the wrapper comes unsealed during heating, or breaks, recontamination as well as drying out will result.

EXPERIMENTAL

Loaves of wrapped, sliced white bread (20 oz. minimum weight) and wrapped Boston brown bread (16 oz. minimum weight) were used in these experiments. A three kilowatt high frequency unit, manufactured by the Federal Telephone & Radio Corp., was employed. It operated at a frequency of 14 to 17 megacycles, had a rated input of 4.6 kilowatts and a rated output of 3 kilowatts. The sample to be heated was placed directly upon the bottom electrode with an air space of ½ to ¾ inch between the upper surface of the loaf and the upper electrode. A thermometer was used to measure the internal temperature of the loaf. In white bread it was inserted from the end, and in Boston brown from the side of the loaf.

FIG. 2. Boston brown bread 14 days old. Left—heated to 140° F. by electronic heat. Right —control.

Wrapper and loaf were pierced with an awl and the thermometer inserted so that the bulb was at the middle of the loaf. Thermometer and awl were dipped in 95 percent ethyl alcohol prior to use to sterilize them. After being heated, the loaves were cooled with an electric fan. They were then stored at from 75° to 85° F. and examined periodically for mold growth.

RESULTS AND DISCUSSION

The first sliced white bread tried was wrapped in waxed paper. This material was found to be unsatisfactory, as the wax softened when the bread showed an internal temperature of about 100° F. It was evident that the wrapper heated more rapidly than did the bread, as the melting point of the wax on the wrapper is 130° F.

On heating to higher temperatures, the wrapper became unsealed and the loaf fell apart. Glassine papers capable of heat sealing and having moisture-vapor proof characteristics were next used. One was coated with Marbon B, a form of cyclized rubber, and the other with soluble Saran. The loaves were heated to 140° F. Between 125° and 140° F. the papers became tacky, but they did not break or unseal. On cooling, the tackiness disappeared, but some of the original surface gloss was lost. These loaves showed no mold growth after twelve days' storage. For a transparent wrapper, cellophane was used. This did not break nor become unsealed in any of the heating treatments employed.

Cellophane wrapped loaves of sliced white bread were heated at temperatures ranging from 125° to 151° F. (Table 1). In some instances a holding period was

TABLE 1

Treatment of Wrapped Sliced White Bread with High Frequency Heat

Sample No.	Final temp. deg. F.	Heating time seconds	10 minute holding	Mold after		
				4 days	7 days	10 days
1	125	20	no	—	+	+++
2	125	20	yes	—	—	++
3	130	27	no	—	+	+++
4	130	27	yes	—	+	+
5	135	35	no	—	+	+
6	135	35	yes	—	+	++
7	140	47	no	—	—	—
8	140	47	yes	—	—	—
9	145	53	no	—	—	—
10	145	53	yes	—	—	—
11	150	59	no	—	—	—
12	150	59	yes	—	—	—
13	control	....	.....	+	++	+++
14	control	....	.....	+	+++	+++
15	control			+	++	+++

— No mold growth.
+ Slight mold growth.
++ Pronounced mold growth.
+++ Heavy mold growth.

used. This was accomplished by leaving the loaf between the electrodes for ten minutes after the desired initial temperature had been reached and the current turned off, and by turning on the current periodically to check any drop in temperature. The bread heated rapidly, requiring only 20 seconds to bring it to 125° F. and about a minute to reach 151° F. No mold development was noted after a 10-day storage period in any loaves that were heated to 140° F. or above. The use of the ten-minute holding period gave no better control than did just bringing the loaves up to 140° F.

Loaves of Boston brown bread were treated in the same manner as the white loaves. Arcing occurred between the upper electrode and the edges of the cylindrical loaf, and resulted in some burning at those points. This difficulty was overcome by rounding the edges of the loaf so that there were no corners adjacent to the electrodes. As with the white bread, heating to 140° F. gave sterilization.

Three groups of wrapped sliced white bread samples consisting of fresh, moldy and stale loaves were sterilized at 140° F. and stored for seven days. At the end of that time, no mold was present on either the fresh or stale loaves and the growth of mold had been checked in the moldy loaves. It was noted that stale bread had been refreshed by the heating. To investigate this effect more fully, four-day-old loaves

of wrapped, sliced white bread were heated to 140° F. and compared with freshly baked loaves and with control loaves that had not been treated. Immediately after being heated, the crusts of the loaves were damp. This condition was caused by moisture being driven from the loaves and condensing on their outer surfaces and on the inner surfaces of the cellophane wrappers. After the loaves had been held for a few hours at room temperature, it was found that this surface moisture had been completely reabsorbed. Although the flavor and consistency of the heated loaves were good and far better than those of the controls, the treated bread could not be considered to be as good as freshly baked. Boston brown bread was refreshed in the same way.

Thiamin determinations were made on some of the loaves of white bread that had been heated to 140° F. It was found that the treatment did not decrease the amount of thiamin.

CONCLUSIONS

1. Both wrapped sliced white bread and Boston brown bread may be made sterile in regard to mold by heating to 140° F. by means of high frequency heat. This heating also has a refreshing effect upon stale bread.

2. Bread that is to be heated in this manner should be wrapped in a moisture-vapor proof wrapper that will not lose its effectiveness during heating or subsequent storage.

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ELECTRONIC REGULATION OF PROCESSES IN FOOD INDUSTRIES

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INTRODUCTION

The objects of this paper will be to examine regulation in general, to locate the part of regulation in which electronics serves its most useful purpose, to examine the manner in which electronics functions in regulation and to describe several examples of the application of electronics to regulation.

The above outline will call for a review of fundamental principles of regulation, some of which are elementary in nature. This plan may be justified, since it will provide the means for properly evaluating new devices in terms of existing knowledge. In addition, it should provide a basis for unifying the mass of data and publications on regulation equipment which confronts the food technologists today.

THE ELEMENTS OF REGULATION SYSTEMS

Two terms, control and regulation, require definition. Control is a part of regulation. A control element or system provides a means of adjusting the value of a variable. Two examples are: (1) a valve is a device by which the flow of gas to an oven burner may be increased or decreased, (2) a rheostat may control the current to an electric-oven heater element. In both cases, the variable is the temperature of the oven.

When a variable is controlled within certain limits, the system which accomplishes this is a regulation system. The control is operated to keep the variable within certain limits which are determined in accord with the relation between the condition prevailing at any instant and the condition required. Consequently, a regulation system involves more than one element in addition to the control unit.

Regulation may be manual or automatic. Normally, a regulation system may be considered to be of the manual type if the control of the variable within limits is secured by the direct action of a human operator. For example, if an operator observes an unduly high value of steam pressure in a retort and adjusts the steam inlet valve sufficiently to secure a normal steam pressure, we have a manual regulation system. In automatic regulation suitable devices are provided which by themselves and without the assistance of an operator secure the desired regulation of the variable. Thus, in the example given above, the operator would be replaced by one or more devices which will automatically adjust the steam inlet valve so that the pressure within the retort stays within the specified limits. The particular devices involved may take various forms depending upon factors of convenience, cost, or specific requirements of the operation. In this paper, only automatic regulation will be discussed.

While a regulation system is an entity in itself, its use is in the operation of a process, and, since it serves the function of holding a variable of the process within certain limits, it is, therefore, an integral part of the process system. It is necessary, therefore, to examine the elements of a process system in order to locate the regulation system. In doing this, the first point to note is that the regulation system concerns itself only with the particular variable in question. Consequently, the rest of the process system can be disregarded and we arrive at something which can be diagrammatically represented as in Fig. 1.

In Fig. 1 the agent is the quantity which is to be controlled. The action is the manner in which the agent is utilized in producing the effect. The effect constitutes the change in the variable. The variable is the item which is to be regulated within limits. This abstract depiction of a process from the standpoint of one variable might be made clearer through illustrations. For instance, in a process where a desired temperature is being secured through the use of electric heater, the agent would be the current, the action would be the conversion of current to heat through the resistance wire, and the effect would be the temperature rise. In another case, in which a desired level of liquid in a tank is being maintained, the agent is the liquid flowing in or out of the tank, the action is the filling or emptying of the tank, and the effect is the change in level produced by this action.

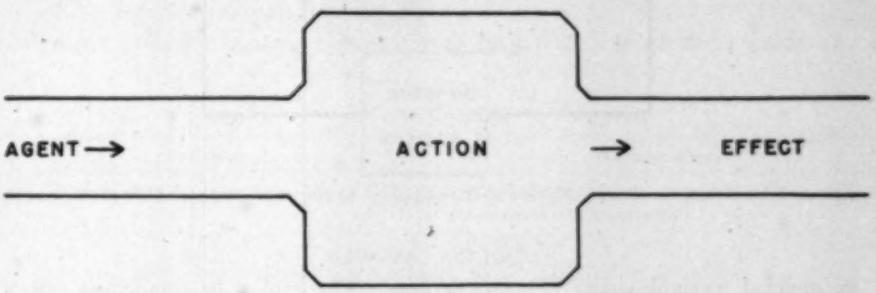

FIG. 1. The elements of a process system involved in the regulation of a single variable.

Now that we have noted what part of a process in general is involved in a single variable of the process, our next step is to apply in general the proper regulation system to that variable. In Fig. 1 we saw that the agent produced the effect or change in the variable. Our purpose in regulation is to limit the magnitude of the changes in the variable. Consequently, our regulation must be secured through control of the agent. This control is secured by quantitative measurement of the magnitude of the effect and limitation of the amounts of agent made available to the system to secure values of the variable within the desired limits. A regulation system, therefore, involves at least three elements: (1) a calibrated sensing device to detect and measure the magnitude of changes in the variable, (2) a device for operating the control element at a particular value of the variable (set-point element), (3) a control device actuated directly or indirectly by the sensing and set-point elements, and acting upon the agent. This is illustrated diagrammatically in Fig. 2.

In addition to these three essential elements it may be necessary or convenient to employ other devices for various purposes. For instance, the action produced by the agent does not occur instantaneously, but involves a time lag. If this time lag is large, it may be necessary to introduce compensation in order to avoid overshooting and undershooting (called "hunting"). In most cases, the sensing element does not produce enough power to operate a control element. The impulses from the sensing element, therefore, require amplification. In certain instances, the process may involve more than one variable and it may happen that a second variable will affect the regulation system of the first, thereby requiring a compensator to eliminate this effect. The list of auxiliary units can be extended almost indefinitely, depending upon the particular circumstances.

In this paper, discussion will be limited to systems involving only: (1) a calibrated sensing element, (2) a set-point element, (3) an amplifier and (4) a control element.

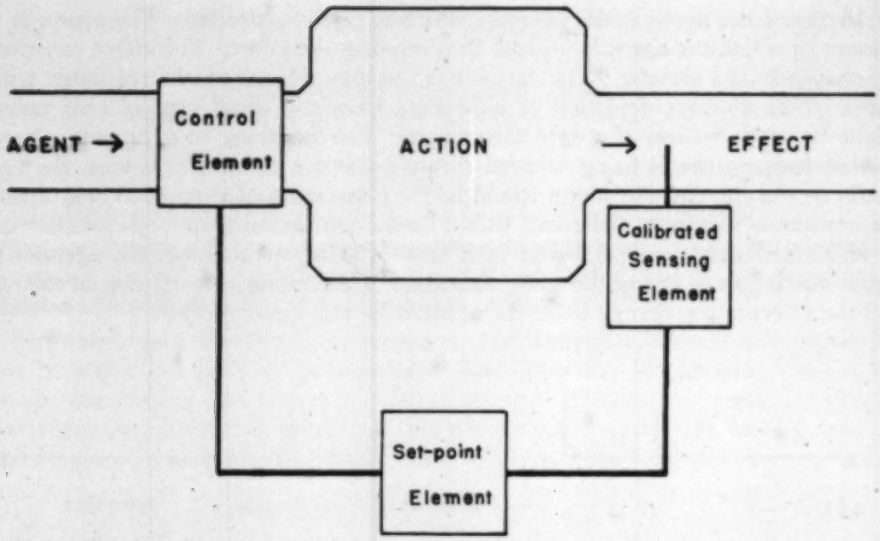

FIG. 2. The elements of a regulation system applied to the regulation of a single variable.

PROCESS VARIABLE

In general, variables may be of two types. There may be quantities which, by the nature of the process, will vary more or less of their own accord, and these might be called "indeterminate" variables. On the other hand, there may be quantities which normally do not vary but which may be made to vary through the application of the proper agent; these may be called "determinate" variables.

It is impossible to classify a variable as to determinate or indeterminate without an exact and detailed knowledge of the process involved. Temperature, for instance, in a given process might vary in a random fashion as a result of chemical action, and yet, in another process, temperature may be produced and regulated within very narrow limits. Some of the more important variables which may be subject to regulation are listed as follows:

Temperature	Time
Pressure	Liquid level
Speed	Moisture (in solids or liquids)
Flow	pH
Humidity	Composition

TYPES OF THE VARIOUS BASIC ELEMENTS OF REGULATION SYSTEMS

Control Elements. The function of a control element is to limit the amount of a particular agent entering a process. The control action may be a simple on-and-off arrangement such as an electric switch, or it may involve a throttling action in which the amount of the agent made available to the system is proportional to the demand. An example of the latter is a valve. In most cases, a throttling device will admit an amount of agent directly proportional to the amount of operation of the control element. The response of the control element is said to be linear in such cases. In special cases, however, it may be desirable to have a non-linear response, the exact response being fitted to the requirements of the particular case. For instance, a valve may be used as a control element admitting a liquid to a system, but because of special requirements may open only to the extent of 10 percent in the first 50 percent of travel.

In general, control devices may be classified as one of the following four: (1) valves, (2) switches, (3) louvres, (4) rheostats.

While control elements may be classified as indicated, the physical form may vary considerably. For example, an electrical switch may be a simple knife switch, or the contacts of a relay, or a mercury switch, or an electronic tube. The function, however, in each case is to interrupt the flow of electric current.

Sensing Element. The entering agent, as we have seen, results in an action which produces an effect. The sensing element indicates this effect and, when properly calibrated, measures the magnitude. In general, the important requirements of a sensing element are: (1) that it respond to the effect in question, (2) that it produce a response of a character which can be utilized in a regulation system, (3) that its power requirements be small (*i.e.*, that it be sufficiently sensitive), and (4) that its response be rapid.

The more ordinary sensing elements may be grouped as given in Table 1.

TABLE 1
Sensing Elements

Variable	Sensing element
Temperature	Liquid thermometer Resistance thermometer Thermocouple Bimetal strip Bellows
Pressure	Bourdon Bellows Manometer Ionization gauge
Speed	Tachometer-generator Speedometer Centrifugal element
Flow	Orifice producing pressure differential Positive-displacement meter Rotary meter Rotameter
Humidity	Wet-dry-bulb liquid thermometer Hair hygrometer
Time	Chronometer Electric condenser-resistor combination Dash-pot
Liquid level	Probe Float Pressure gauge Gauge glass
Moisture	Conductivity cell Dielectric-constant-sensitive-cell Specific-gravity-device Refractometer
pH	Glass electrode Antimony electrode
Composition	Spectrophotometric devices Refractometer Polarimeter Conductivity cell Tyndallometer

For regulation purposes, the sensing elements must be calibrated in order to measure the magnitude of the effect produced by the agent. This calibration may take various forms, and may be physically located in one of several places. For instance, it might be the scale on a thermometer, or the setting on a bimetal strip, or a potentiometer calibrated in degrees temperature for a given thermocouple. Convenience, available power and other requirements determine the location. Some of the possible places are: at the sensing element, after the amplifier, or at the control element.

Set-Point Element. Regulation implies limits of variation. The calibrated sensing device provides the means of determining the magnitude of the variation. The set-point device determines the point at which the control element operates. The limits of variation generally are set by a number of factors such as: (1) the sensitivity of the sensing element, (2) the time response of the sensing element, (3) the time response of the amplifier, (4) the time response of the set-point device, (5) the time response of the control device, (6) the time required for the effect to occur as a result of the action of the agent, (7) the amount of anti-hunt action introduced into the regulation system.

The set-point device may be of a variety of forms, depending on convenience and requirements. Some of the more common forms are:

Electric switch-scale combination
Bellows-pressure combination
Weight-lever combination
Spring tension-lever combination
Electric condenser-resistor combination

Amplifier Element. As we have seen, basically, a regulation system does not require an amplifier. However, in general, the power available from a sensing element is not sufficient directly to operate a control element. The function of an amplifier is to make available to the control element sufficient power to operate it in accord with the demand indicated by the sensing element. The regulation system, including the amplifier element, may be represented diagrammatically as in Fig. 3.

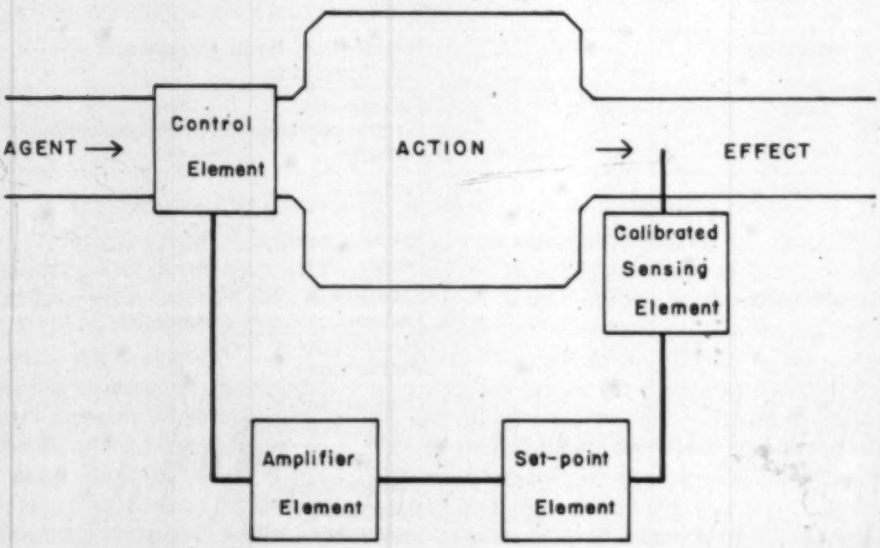

FIG. 3. The elements of regulation system including the amplifier element.

Obviously, there can be many amplifying schemes. The ordinary ones can be grouped as follows: pneumatic, hydraulic, mechanical, electric, electronic.

Of these varieties of amplifiers, only the electronic amplifier will be discussed in detail. Electronics enters the general scheme of regulation principally and most usefully in the amplifier. The electronic device usually is a part of the amplifier element, and acts to receive the minute signal from the sensing element, to amplify it, and to make available sufficient power to operate the control element. There are many ways to carry out this function electronically, and the choice of a particular method will be governed by the specific requirements, by reliability, stability, cost, and convenience. In this paper, certain selected electronic methods of amplification will be discussed. Preliminary to this discussion, it seems advisable to review certain pertinent electronic principles.

Electronics is that branch of science and technology which relates to the conduction of electricity through gases or *in vacuo*. Physically this means in electron tubes in which the principal current is a simple movement of electrons through space. The engineering aspect of the subject deals with the control and utilization of this current. The definition, therefore, indicates that every electronic instrument has in it at least one electron tube, such as a vacuum tube, a phototube, or a thyratron (gas tube). In its most simple form, a vacuum tube is composed of two elements in an evacuated glass or metal envelope: (1) a heated filament as the source of electrons and (2) a plate maintained at a high positive potential (with respect to the filament) which attracts the electrons to form the current. By interposing a third element, the grid, between the filament and plate, it is possible to control the current flow. This may be shown diagrammatically as in Fig. 4.

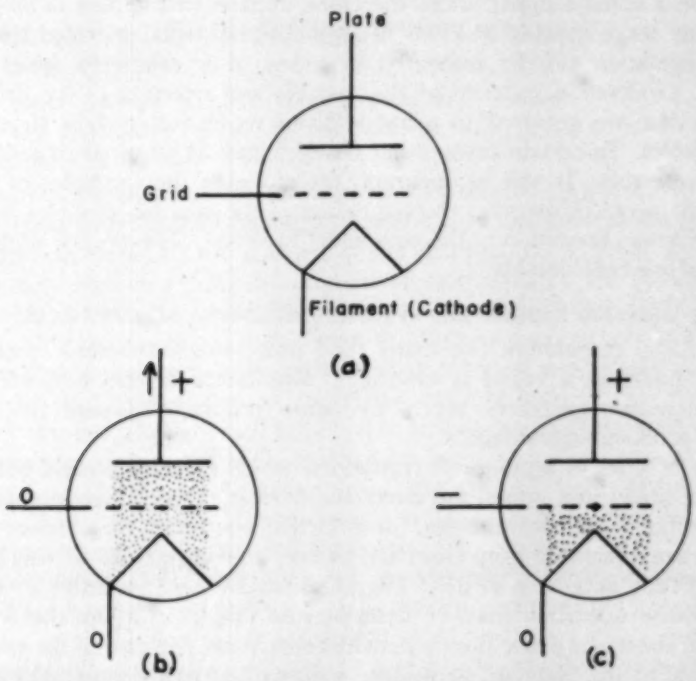

FIG. 4. The action of the three element vacuum electron tube as a switch. (a) The elements, filament, grid and plate, schematically portrayed. (b) Electron flow filament to plate when no voltage is applied to grid. (c) No electron flow filament to plate with negative voltage on grid.

Control of the filament to plate current is secured by varying the grid potential, or bias. When no voltage is applied, the grid has no action. As it is made more negative it impedes the filament-to-plate current, and if made sufficiently negative, may stop the current flow completely.

The three element tube, therefore, acts as a valve controlling current flow, and if the grid is made sufficiently negative, stopping it entirely. In a particular scheme control of current within limits may be desired or complete cessation may be required. In the latter case, the tube acts more as a switch. The power used in controlling the grid potential and, consequently, the plate current, is small, on the order of a milliwatt or less. The power controlled is much greater than the power applied; consequently, the tube acts as an amplifier. It is, therefore, useful in regulation systems between the sensing and control elements.

A thyratron is a gas-filled tube which has the same basic elements as a vacuum tube, and with somewhat different circuits can be made to perform the same functions. It possesses a higher current-carrying capacity than the vacuum tube and is sometimes used where this is necessary or convenient.

In addition to the three element electron tube, there are other electron tubes which are useful in regulation systems. However, normally such tubes are limited to special purposes and cannot adequately be described in a paper of this kind. It is the purpose of the remainder of this paper to describe in some detail typical applications of the three electrode tube to the regulation of certain variables encountered in the food industries. It should be noted that frequently the regulation system employed is suitable with little change for the regulation of a variety of variables. For instance, it is immaterial whether voltage is developed by a thermocouple or the flow of current through a resistor, as long as the regulation system is designed to operate on a voltage signal. It is, therefore, apparent that there is no great need for an unduly large number of kinds of regulating systems, provided the variables requiring regulation can be measured in terms of a relatively small group of parameters. Calibration in terms of the variable and selection of the proper range may be all that are required to adapt a given regulation system to any one of several variables. In certain cases, other changes may be required in order to make the system operable. It will be apparent, therefore, in the examples of regulation systems to be given below, that the regulation of the specific variables described is not necessarily the limitation of the equipment involved. The proper adaptation can extend the scope considerably.

SPECIFIC REGULATION SYSTEMS EMPLOYING ELECTRONICS

Liquid Level Regulation. In many food processing operations, control of the height of a liquid in a vessel is desirable. Regulation of this liquid-level height through automatic equipment serves to insure proper level, and frequently has appreciable economic advantage.

The newer types of liquid-level regulators, which serve to control automatically the height of liquid in a vessel, are electronic devices. Over older mechanical float-types they offer several advantages, the principal one being the absence of moving parts which are difficult to keep clean and to keep moving freely. In this application the electron tube acts as a switch. Fig. 5 illustrates schematically a very simple regulator whose operation may be described as follows: When the level of the liquid is low, the upper probe does not make contact and the grid of the tube is at the same potential as the filament, permitting a flow of current through the tube. This current energizes the coil of the relay, keeping its contacts open. As a result, the solenoid valve is not energized and the liquid flows in. When the level reaches the

probe, the minute current which flows through the liquid also flows through the grid resistor, R, causing the grid to become negatively charged. This stops the current flow through the tube and relay. The contacts close and the solenoid valve is actuated to stop the flow of liquid until the level drops below the probe. The cycle is then repeated.

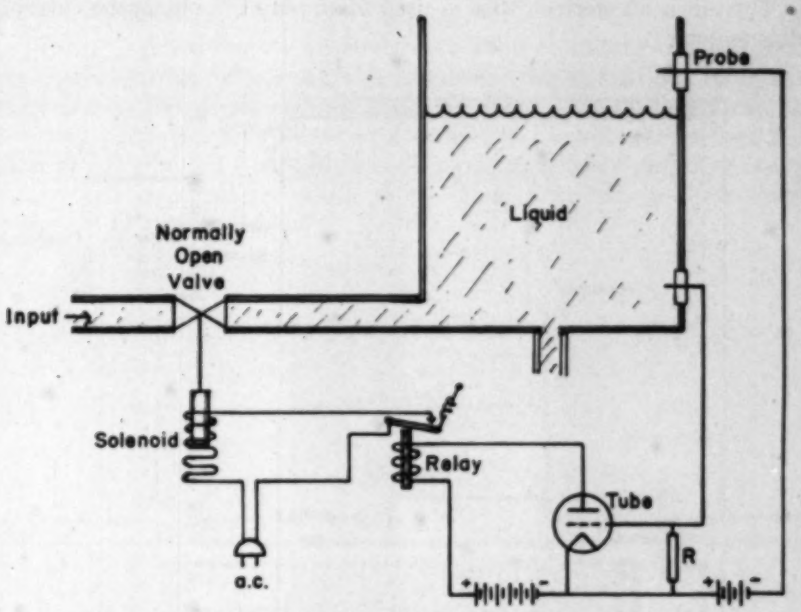

FIG. 5. Liquid-level regulation system.

This control may be adapted for use with any conducting liquid. It may be applied to the automatic control of the level of milk in vats, boiler water level, water in overhead tanks, etc.

Illumination Regulation. An application of electronic regulation which is definitely associated with the food industries but not immediately with the processing of foods, is the regulation of the amount of the illumination of plant or office areas which normally receive a sufficient amount of natural light. On cloudy, foggy, or rainy days the illumination must be augmented by artificial illumination. On such days, north light may perform cycles from as much as 1000 to 200 foot candles. If the amount of illumination on the work benches or desks is manually regulated and depends upon the judgment of an individual, one or both of two things usually occur: (1) the natural light will fall to such a level as to cause severe eye strain before the condition is noted and corrected by turning on the lights, or (2) when the natural light reaches a satisfactory level, the artificial lights are forgotten and left on. The first case results in unnecessary fatigue and the second in unnecessary expense in power and bulb replacement costs.

By the proper use of a phototube and an amplifier tube, control may be made automatic. A phototube is an electron tube which converts light to a flow of current. It has two elements in an evacuated glass envelope: (1) a cathode which emits electrons when illuminated, and (2) an anode which attracts the electrons. The flow between the cathode and anode forms a current. Within limits, the current is proportional to the illumination.

The basic scheme for such a regulation system employing a phototube is shown in Fig. 6. As has been pointed out, when light falls on a phototube, it will conduct a minute current. This current is on the order of ten millionths of an ampere. This current is much too small to do the work required to operate directly a relay whose points are capable of switching on or off the relatively large currents supplying the lamps. Therefore, an electron tube is used to amplify the phototube current in the following manner:

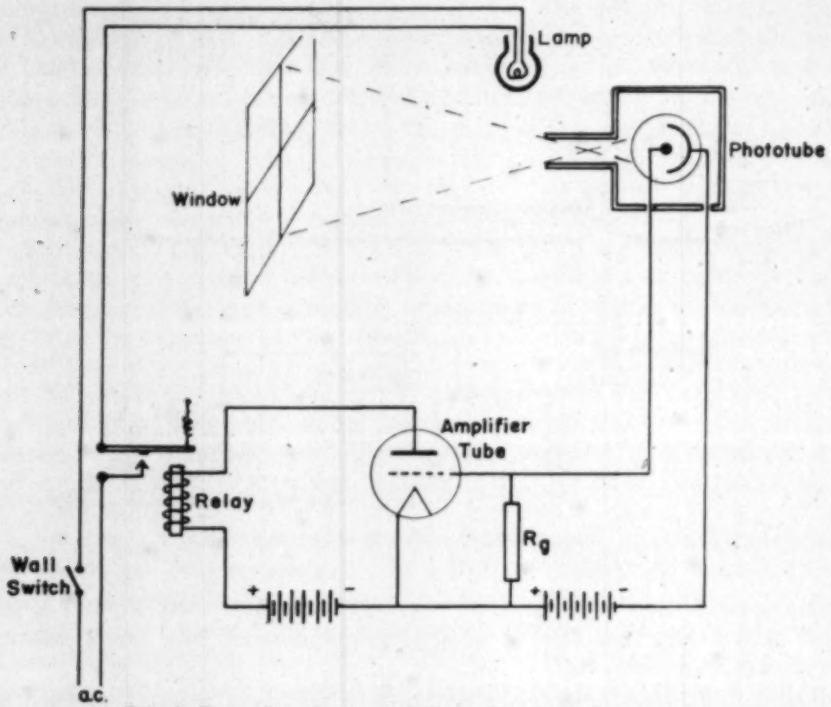

FIG. 6. Room illumination regulation by phototube system.

The phototube is placed so that it "looks" out of a window. When there is sufficient light, current flows through phototube and through the resistor, Rg. This causes the grid of the tube to be negative, which reduces the current through the amplifier tube and through the relay coil to a very low value. As a result, the circuit to the lamp is open and the lamp is off. When the outside light drops below a definite level, current through the phototube and Rg is reduced. This decreases the negative voltage on the grid. In turn, more current flows through the relay, pulling down its armature and completing the lamp circuit when the wall switch is closed. If the natural light level rises again, the lamp will turn off automatically.

A similar system using a phototube may be used for regulating the density of smoke in a smoke house or in a boiler stack. In these cases, beams of light are projected through the house or stack onto phototubes. When the smoke exceeds a predetermined density, the intensity of the light reaching the phototubes will be so low that the relays will pull in operating dampers to reduce the smoke.

Another possible use for phototubes is the regulation of the turbidity or color of a liquid. A light beam may be projected through a section of glass tube carrying the

liquid. A phototube may receive the light and detect and correct a turbid or off-color condition or stop the flow of the liquid.

pH Control. In a number of foods, pH value has considerable significance. Frequently it is possible to add materials to secure a desired pH value. Particularly in continuous operations, the automatic control or regulation of pH may be most effective and economic.

The sensing element may be an electrode system consisting of a glass electrode and a calomel electrode. The voltage developed by this system is a function of pH and temperature. By proper compensation, the effect of temperature can be eliminated so that pH is the only factor in determining the voltage developed. In the regulation of pH through use of a glass electrode system, an amplifier is required, due to the high electrical resistance of the glass electrode, and the consequent minute amount of current developed.

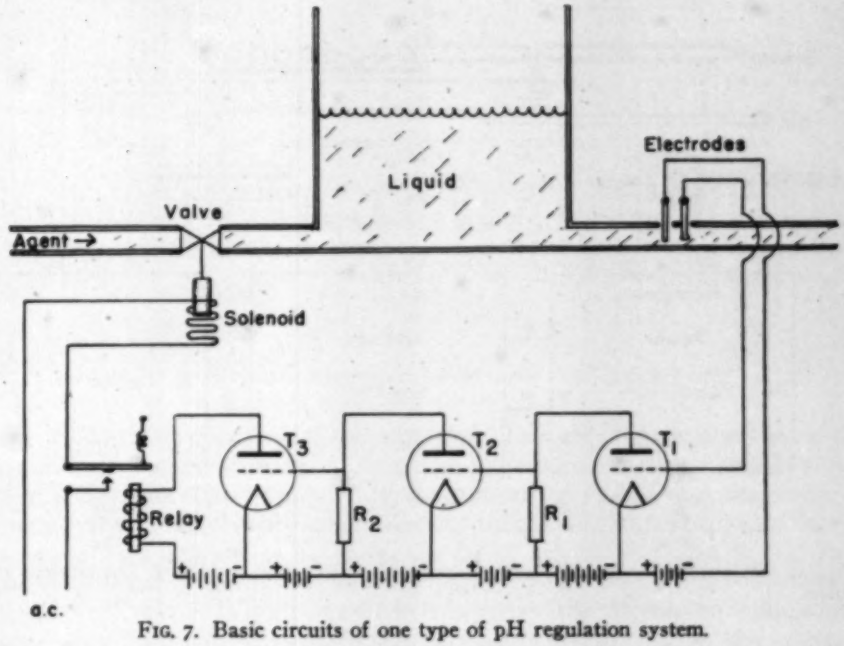

FIG. 7. Basic circuits of one type of pH regulation system.

The vacuum tube is ideal for amplification because it requires practically no current in the grid circuit to control a large current in the plate circuit. Since the current developed by the glass electrode system is extremely minute, two or three stages of amplification are usually required to operate a suitable relay. The fundamental circuit of one type of pH regulation system is shown in Fig. 7.

The voltage which appears between the two electrodes controls the flow of current through the tube T1. This current also flows through resistor R1 producing a voltage across it which is a simple magnification of the electrode voltage. The larger voltage then serves to control the current through tube T2 which produces a still greater voltage across resistor R2. After being amplified a third time, the current is of sufficient magnitude to operate a relay, the contacts of which complete a circuit controlling the input of liquid which is capable of varying the pH.

Temperature Regulation. Temperature regulation enters many phases of food processes, such as canning, pasteurization, cooking, sterilization, etc. Temperature regulation systems have, therefore, received much study.

One of the most ingenious applications of the field of electronics to regulation is particularly well adapted to the measurement and regulation of temperature. The details of its operation are too numerous to be completely discussed at this time, but perhaps some of the basic considerations can be brought out. In order to proceed stepwise, Fig. 8 shows the principal sections of the instrument.

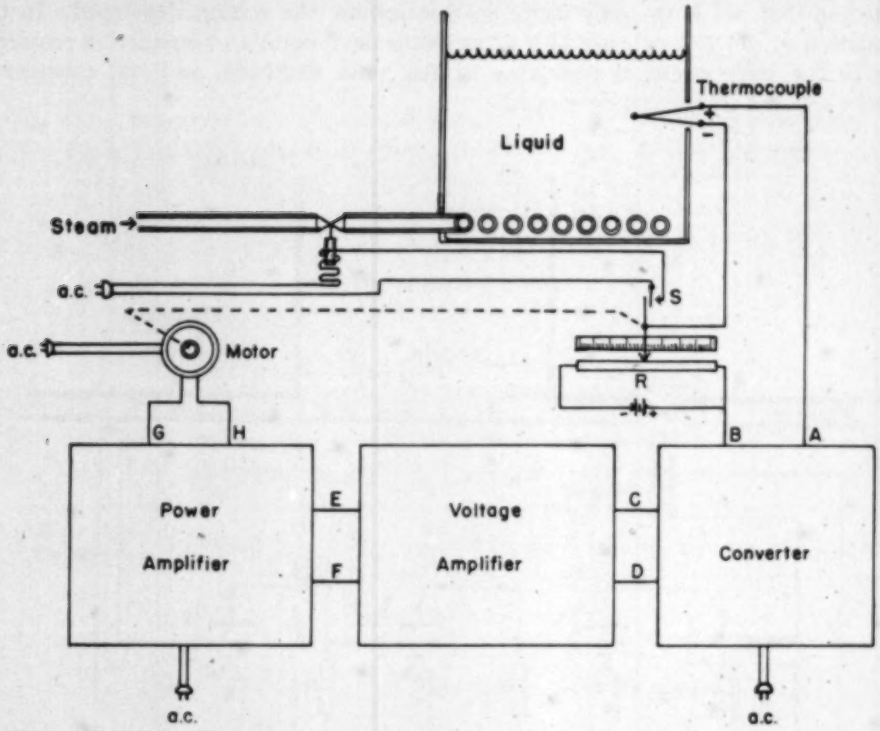

FIG. 8. Temperature regulation system employing electronic amplifier. The sections of the assembly.

The functional operation of each may be outlined as follows: In accordance with temperature changes, a thermocouple unit generates a few millivolts between its terminals. Another source of voltage is connected across the slidewire R, and this voltage is in opposition to the thermocouple voltage. If the two are equal, zero voltage appears between A and B. However, if the thermocouple voltage is larger, A will be positive and B will be negative, and if the thermocouple voltage is smaller, A will be negative and B will be positive. If, by any means, the arm is moved across the resistor until no voltage appears between A and B, then its position on the scale when properly calibrated can be read as temperature.

The converter, voltage amplifier and power amplifier serve simply as a means for using the very small thermocouple voltage to drive the balancing motor. The shaft of this motor is connected to the arm of the resistor, and the instrument is so designed that any time a voltage appears between A and B, the motor starts and drives the arm in the proper direction to reduce the voltage to zero. As a

consequence, the arm is almost continuously over a point on the scale which represents the temperature. How the motor is made to perform in such a manner will be shown.

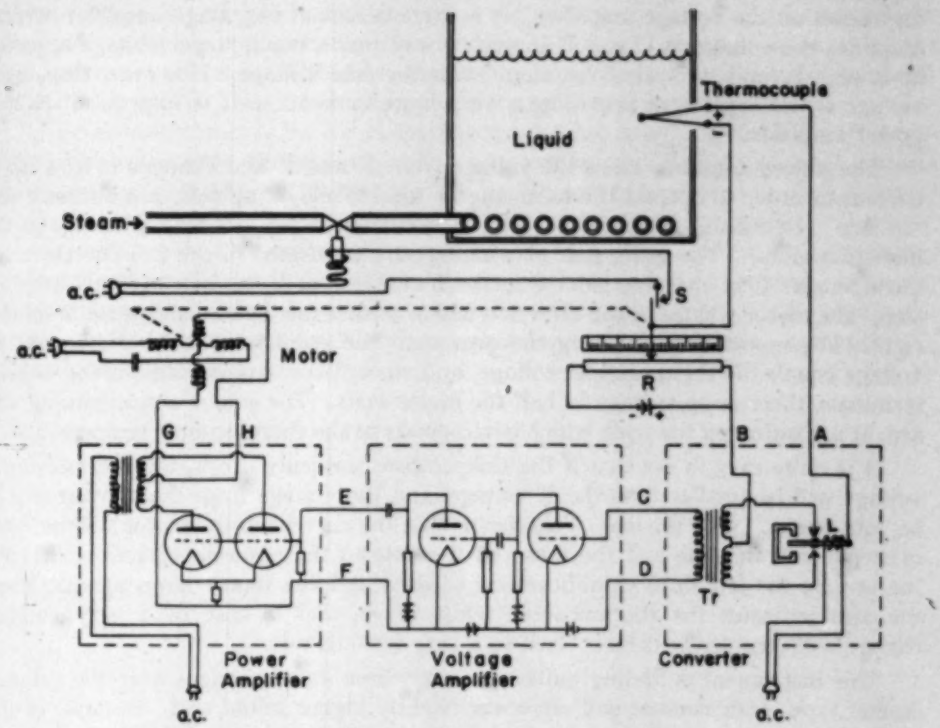

FIG. 9. Schematic diagram of temperature regulation system.

Fig. 9 shows the operation of the converter. The coil L is energized by ordinary 60 cycle line voltage and serves to drive the vibrating reed which acts as a switch contacting first one end of the primary of transformer Tr and then the other. This produces across the secondary an alternating voltage with a frequency of 60 cycles per second. This unit serves to change the direct current produced by the thermocouple to alternating current. Another important point is that if the thermocouple voltage is such that A is positive and B is negative, the alternating voltage will be "in step" with the line voltage, while if A is negative and B positive, the voltage will be "out of step." If the thermocouple voltage is exactly equal to the bucking voltage at R then there is no converter output voltage.

Therefore, at this point, we have one of the three following conditions:

1. If the pointer indicates the exact temperature of the thermocouple, the thermocouple and bucking voltages are equal; there is no voltage at A and B or at C and D.

2. If the thermocouple temperature suddenly rises, the voltage at *R* is lower than the thermocouple voltage, with the result that A is positive and B is negative; and the alternating voltage at C and D is "in step" with the line voltage.

3. If the thermocouple temperature suddenly drops, the voltage at *R* is higher than the thermocouple voltage, A is negative and B is positive; voltage at C and D is "out of step."

To analyze the rest of the instrument, let us consider a specific case: The indicator is pointing to a lower temperature than the thermocouple temperature; A is positive, B is negative and the "in step" alternating voltage at C and D is impressed on the voltage amplifier. It is a conventional two stage amplifier which amplifies the voltage at C and D in such a way that a much larger voltage appears at E and F, and it is also "in step" with the line voltage. However, this high voltage is not capable of providing a very large current, so it is impressed on the power amplifier.

The power amplifier takes the voltage from E and F and changes it to a high current in order to operate the balancing motor. While doing this, it maintains the "in step" relationship with the a.c. line. The current is fed into two windings of an induction motor. The other pair of windings are connected to the a.c. line through a condenser. One characteristic of such a motor is that if the two currents are "in step," the motor rotates in the direction which pushes the arm on slidewire R to the right. The motor keeps moving the arm until the point is reached where the R voltage equals the thermocouple voltage, and since there is no voltage at the output terminals, there is no voltage in half the motor coils. The motor stops, leaving the arm at a position on the scale which corresponds to the thermocouple temperature.

It is quite easy to see that if the temperature suddenly drops, the thermocouple voltage will be smaller than the R voltage, and the voltage from the converter will be "out of step" with the line. This means that the current to the motor will be "out of step" with the line and the motor will rotate in the opposite direction, driving the arm to the left until equilibrium is reached and the motor stops again. Thus the arm indicates the thermocouple temperature, and in case of a very sudden change will completely correct itself in a very few seconds.

This instrument is finding quite wide use where its advantages over the galvanometer type of instrument will offset the slightly higher initial cost. Because of the use of electronics, it offers several advantages. Since there is no delicate galvanometer, it is unaffected by any reasonable vibrations; it can be used in any position; there are a minimum number of moving parts; its sensitivity can be made very high; and its response to a temperature change is very rapid.

By including a suitable set-point element, for instance, an electric switch S, mounted on slidewire R, the system can be employed for regulation. The set-point element actuates any suitable heat or refrigeration input control device such as a valve.

GENERAL CONSIDERATIONS

In the discussion presented in this paper, many items have been omitted. This has been necessary in the interest of brevity and clarity. Reference to some of these omissions can be made in a general way.

The four electronic systems described in some detail are, of course, not the only possible systems. The ingenuity of the electronicist seems to be without limit, and he usually can rise to the demands of most any problem. The result has been the development of a multitude of systems. Those described in this paper are given merely as examples.

In the description of the four systems given in this paper there were many details simplified or omitted. For example, batteries were frequently indicated as sources of current. In practice, rectifier units to permit operation off alternating current lines would be used. Some units which make for better regulation have not been described. Examples of these are anti-hunting devices. In general, it would

be difficult to construct an operable system from the details given in this paper. Many practical features have been omitted.

As has been indicated previously, a given unit can be adapted to the regulation of more than one variable. This is true if the several variables in question can be converted to the proper quantity (for instance, a voltage) through selection of the proper sensing element. Therefore, the scope of application of any one of the units described is greater than the single application mentioned indicates.

In conclusion, it may be stated that electronics has been of assistance in regulation systems, mainly through its ability to provide amplification of weak signals from sensing elements and, in that way, to provide enough power to operate control elements. Electronics, in doing this, has improved existing regulation systems, (1) by eliminating or reducing the number of moving parts, and (2) by eliminating delicate parts subject to disturbance from vibration, etc. In general, however, electronics has extended the scope of regulation and provided the food technologist with additional tools for regulation of processes. It is the food technologist's function to apply these new tools.

PLANNING FOR GREATER EFFICIENCY IN THE OPERATION OF DAIRY PLANTS[1]

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It is becoming increasingly evident that there is great need for us to give considerable attention to increasing the efficiency of plant operations. In many markets we have little or no control over the price we pay the farmer for milk nor over the selling price. This means we have a relatively narrow margin which is under our control and it is obvious that we must exert greater efforts to bring about more efficient operations.

The inefficient plant is going to pass out of the picture. The successful dairy business of the future will be no accident but it will be just as much a matter of strategy and planning as the winning of a major military engagement. Management must not only meet today's problems but must plan for tomorrow. The Dairy Industry has made great strides in technological improvements but from an engineering standpoint there are many inefficiencies in this industry. It looks as though the greatest improvements in plant efficiency will be due to engineering advances during the next ten years.

During the past two years much time has been spent in traveling in an attempt to help dairies in improving the efficiency of their operations. For this discussion, I have selected some of the principal factors found to cause inefficiency in dairy plants.

1. MANAGEMENT

The difference between success and failure depends largely upon an alert management in dairy plants. Regardless of what the immediate cause of inefficiency may be, the whole thing traces back to management. Many dairymen have inquired: Why is the quality poor; why can't they have a plant with good housekeeping; or why is their cost of processing so high?

I have compared such plants to others which are operating efficiently with a good product, high morale, and fine operations. We always come back to the same point and that is: no business can be successful without good management. There is no secret to good plant operations.

The successful operator of the future must not only have good business judgment but he must also know how to handle labor and must have some understanding of the technical problems involved in plant operations. Most important of all, he must surround himself with men who know how to run plants efficiently. This suggests our next item for discussion, namely, intelligent personnel.

2. INTELLIGENT PERSONNEL PROGRAM

You may design the most beautiful and modern plant in existence but without people it becomes merely a pile of brick and mortar. It is the people in a business that make it a success or failure. No business can prosper and grow without someone in the organization taking time to develop an intelligent personnel program that will insure that business sound management and good plant supervision.

Many plants have called on me to help them obtain good technical men to help them in plant operations and in many cases I have been forced to tell them I am helpless to recommend men because their company has a poor reputation in taking

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 19, 1946.

care of its technical men. It is surprising how fast such news travels. If we want good men we must treat them well and pay them in accordance with the value of their contribution. Considerable thought and effort should be given to the entire personnel program not only of technical men but of all men in the organization.

3. GOOD ACCOUNTING SYSTEM

No plant can be operated successfully without a good accounting system. There is no use to hire a good production manager and tie his hands by lack of proper records and costs showing what is going on in the business. To many executives, the office is one of the "necessary evils" of doing business. Consequently, little or no thought is being given to improve the efficiency and to streamline office procedures.

Periodic studies should be made of all reports and all paper work in the entire organization with a view in mind of eliminating unnecessary reports and to introduce new reports which will give the operating personnel more information concerning their operations. These reports should disclose non-profitable items produced and steps should be taken to make a study of the operation to determine the underlying factors contributing to high costs. From such studies steps can be taken to correct the operation and to place it on a profitable basis, or if it is not possible, management may decide to discontinue certain operations which are unprofitable.

During my many appearances before dairy audiences throughout the country in the last year, I have asked one stock question, i.e., "How much is it costing you to produce a pound of steam in your power plant?" Even in audiences of 300 to 500 people, not one has been able to tell me how much it cost to produce steam. I have also asked people how much it costs to wash 1,000 bottles in their plant and many of them have never even given it any thought. Even in the case of butterfat losses I find that little or no record is kept in many plants. In recent weeks I have talked to one large plant operator buying $3,000,000 worth of milk annually and they pride themselves on the efficiency of their operation, yet they have no such thing as a fat loss statement. I'll make you a wager that in 50 percent of the dairies in this country they do not have any real conception of their fat loss picture. I have worked with two plants recently who were losing $50,000 a year through fat losses and were under the impression they were doing a fine job.

If I had to take over some of the businesses not operating efficiently, the first thing I would do is insist upon a good system of accounting.

4. QUALITY CONTROL PROGRAM

Regardless of the size of the operation, all plants should have some well-defined system of quality control. It is not always necessary to set up a large research organization, but at least we ought to have a simple laboratory which can run ordinary dairy tests and someone in the organization should develop a sound quality control program. It is surprising to note that many plants are being built today without even a laboratory in the architect's plans. After the plant is built, someone decides that a laboratory should be included, but no real plans are made in many cases. The principal functions of a Quality Control Program are as follows:

(a) To supervise the procurement of all raw materials;
(b) To develop and recommend good methods of sanitary control;
(c) To develop and supervise processing methods and formulas;
(d) To work with management and the sales department in the development of new products and in the improvement of existing methods.

5. EFFICIENTLY ENGINEERED PLANT

No plant can be operated on an efficient basis unless considerable thought has been given to the development of a well-engineered plant. With the exception of a few large plants, little or no thought has been given to the development of sound engineering plans for the Dairy Industry. Most dairy plants won't even hire an architect, let alone a consulting engineer, to advise them in regard to the building and equipping of their plant. They usually depend upon knowledge and advice which they get from their friends or from equipment manufacturers.

In this respect the Dairy Industry is far behind the parade of food processors. Other food industries realize the need for extensive planning and engineering to obtain efficiency, but we in the Dairy Industry go along from year to year doing little or nothing about sound engineering. We have been depending almost entirely upon the equipment manufacturers for help and guidance along the lines of engineering and we forget that equipment engineers are not always well versed in operating problems. What we need is more good dairy engineers with practical experience in the operation of dairy plants as well as good basic training in the fundamentals of engineering. To be more specific, we might mention a few high spots in connection with the development of engineering plans for a new operation.

a. *Location.* In selecting the location for a new plant, considerable thought should be given to such problems as transportation or availability of railroad sidings and trucking facilities, presence of an adequate water supply, sewage disposal, convenience of workers in getting to and from the plant, adequate room for expansion, and location of the plant in regard to zoning, nuisance from odors, smoke, cinders, etc.

b. *Plant Layout.* Most plants are designed and built without any real thought being given as to whether or not the equipment layout will be satisfactory and efficient. Time after time I have been called in while a plant is being constructed to help in making an efficient equipment layout. Most of the time it is difficult or impossible to make a decent arrangement of equipment under such conditions. We should not construct a building and then try to work the equipment into the building, but rather we should lay out an orderly arrangement of the equipment and then build the building around the equipment. If we could only get the plant operators to sit down with a bunch of cutouts of equipment and place them on a table or drafting board before the plant is designed, then many of our troubles of the future would be eliminated.

We might mention a few key points in connection with the layout which might be helpful:

(1) Try to obtain a natural flow of materials so that there will be no need for pumping back and forth from one side of a building to the other. We must streamline our operations and try to get straight-line flow as much as possible.

(2) In designing dock and garage, load-out, freight, etc., some attempt should be made to have all of these operations on one side of the building to reduce the problem of supervision on incoming and outgoing materials. This is particularly true in a small plant. In medium-sized milk plants, for instance, we usually locate the garage so that it becomes a part of the shipping dock, with icebox, stockroom, bottle storage, etc., all opening into the garage for economy in handling and supervision.

(3) In most milk processing rooms a U-shaped processing layout with a common working space between two lanes of equipment is about the most efficient that can be obtained.

(4) In placing equipment it is common practice in a good layout to leave a minimum space of 24" between pieces of equipment and from equipment to the wall.

(5) When designing conveyors for the handling and moving of materials, we should ask ourself the question as to whether or not the use of a conveyor will really save anything in plant operations. We find in many of the smaller plants that conveyors do not always save money and in numerous cases it is actually more expensive to operate with conveyors than without.

In the case of ice cream plants two items come readily into my mind. Considerable hardening room wall space is needed in the processing room so that such operations as freezing, brick cutting, packaging operation, cup operation and novelty operation can be placed along the hardening room wall without the need for long conveyors. If the arrangement is properly made, most of these jobs can be handled without any semblance of a conveyor. In small plants an L-shaped ice cream processing room around two sides of the hardening room has considerable merit.

c. *General Factory Specifications.* In drawing up the specifications for the contractor and the architect, considerable thought should be given to such items as the following:

(1) Plan for future expansion.

(2) Convenient and well-designed plant locker-rooms.

(3) Red tiled floors for all processing rooms with grout between the tile of 3/16".

(4) Use cove-base tile at junction between floor and walls.

(5) Where windows are used, see that sills are sloping, and where moisture conditions are prevalent, consider the possibility of using wood in place of steel.

(6) For electrical controls it is recommended that the square duct system with push-buttons located in the processing room and automatic starters in the panel room be used.

(7) In designing the heating and ventilating system, see that plenty of fresh air is brought in to dilute the air and thereby reduce humidity and that such incoming air is warmed to prevent condensation and fog. Use enough exhaust fans to remove the diluted air and to sweep the warm air along cold surfaces rapidly to prevent condensate.

(8) Locate sewers so that they will not be in a position where a man must stand in a pool of water and make them of sufficient size to carry away floor drainage readily.

(9) Give considerable thought to lighting and follow more or less the general recommendations issued in the lighting bulletin of the International Association of Milk Dealers.

(10) Put hand-washing facilities in all processing rooms.

(11) Check plant layout and construction with Health Department before proceeding with construction.

(12) Where possible, conceal pipes and conduits, etc., so as to reduce congestion above equipment and to improve the appearance of the plant.

(13) Provide a utility or cleaning room next to the processing room for storage of cleaning materials, equipment, brushes, etc.

6. ENGINEERING PROBLEMS

a. *Boilers.* In deciding upon heavy equipment such as boilers, ice machines, etc., most plants need help from somebody in regard to the engineering of such large expenditures. First of all, it must be decided as to whether or not we will burn coal, gas, or oil. There is no stock answer to this problem, and it must be decided for every location and for every plant. In one large plant recently the local engineer decided to purchase oil when a more careful study of the situation revealed

that coal would supply the steam to them at 40 percent less than oil. In other words, no real study had been made, and only an expert could answer these problems.

Such problems as the following must be considered in deciding upon the type of boiler used:

(1) The quality of the personnel available for operation of the boiler house.
(2) Type of fuel to be purchased.
(3) Size of the operation.

In the case of small plants, where steam consumption is relatively low per 100# milk handled, economy is sometimes sacrificed to obtain a compact and sanitary boiler arrangement. For instance, gas or oil may cost more in certain cases, but because of the neatness of the operation management is willing to pay a bit more for steam. When you get into such large operations as evaporated plants, however, the cost of fuel becomes very important and even small differences such as 10 percent in the cost of fuel would be very important.

b. *Refrigeration.* There is probably more room for improvement in regard to refrigeration in the average dairy plant than in any other operation of the entire plant. This is rather surprising because actually our refrigerating people know a great deal about the problem and very efficient methods have been worked out to make the plants operate efficiently. The biggest trouble is that these refrigerating problems have not been properly sold to management and management has little or no conception of the real problems involved.

We have talked to many owners and general managers of dairy plants in the past few weeks and I am surprised at how little they know about the fundamental principles of refrigeration as applied to their operations. Of course, we can't expect management to be expert in all phases of plant operation and lack of knowledge on such problems can be excused. However, there are people who understand these problems thoroughly and upon whom management can rely for good advice.

In one instance last week, one dairy plant desired to double its processing capacity which would have meant that the ice machines necessary to handle the increased production must of necessity be increased from 50 tons to 100 tons. In this particular plant the principal refrigeration load requiring a machine of 100 tons' refrigeration was raw milk which was received in the period of four hours. During the rest of the 20-hour period the machine refrigeration tonnage required was only 50 tons. In this instance a small latent heat plant is the logical conclusion, yet many plant operators never even heard of a latent heat plant. The engineer may know the value of a latent heat plant, but this knowledge is of no value unless it reaches the ears of management.

I have yet to find a single case where management could not be sold on the purchase of any equipment needed to do the job properly providing that it was explained to them in a complete and concise manner. Management is very cooperative if we can do a good job of selling what we really need in a plant and that is where most of us fail in that we do not get our story to management in a conclusive manner.

To be more specific about refrigerating problems, it is necessary to first determine the rate per hour at which all dairy products will be operated and sit down and figure in the form of a graph the total tonnage required on each operation hour by hour. This *Thermo-Graph* will show at a glance what must be done in the refrigerating plant to be efficient.

There are times when direct expansion is satisfactory and many other times when sweet water should be used. Each plant is a separate problem and each operation should receive considerable discussion as the type of refrigeration needed. We

should not just sit down and order a bunch of compressors, such as 7½ x 7½, 6½ x 6½, and 5 x 5, but rather we should complete the study and determine exactly how many tons of refrigeration are required and at what back pressure each operation must be operated. It is a well-known fact that the higher back pressure at which we can operate our ice machines the less will be the electrical power per ton of refrigeration. An attempt should be made to operate as near to 45# back pressure as the particular job will allow. A good example in this instance is the question of ice manufacture.

c. *Ice Manufacture.* In the manufacture of ice most plants available for use in the Dairy Industry operate at 15-17# back pressure. One new piece of equipment has been on the market for several years and it will manufacture ice at 25-30# back pressure with notable savings in capital investment and horsepower consumption per ton of ice manufactured. Even so, this machine is relatively unknown to the Dairy Industry but is being received with great enthusiasm by other industries. We in the Dairy Industry are slow to find out what is going on in the field of engineering improvements and it is time for us to wake up and get in the parade of modern engineering developments.

d. *Water Treatment.* In designing a new plant, considerable thought should be given to the treatment of water which would be used for boilers, washing equipment, etc. This is a specific problem which must be worked out for each plant and it requires considerable knowledge and technical information.

7. PLANT EQUIPMENT

In regard to the purchase of plant equipment, we would make one general recommendation and that is that each plant operator keep in touch with his fellow dairymen throughout the country and find out what his friends in the dairy business have discovered in regard to the efficiency of certain particular pieces of equipment. Many operators are so busy operating their own plants and having problems of labor, raw materials, etc., that they do not find time to get around the country and see what is being done in other plants. If they would do this, they would keep up-to-date and find, as many others have, that certain pieces of equipment are particularly outstanding and are a "must" for any well-operated plant.

8. MISCELLANEOUS PLANT OPERATING PROBLEMS

In order to improve the efficiency of plant operations, it is suggested that considerable thought be given to the following problems which are encountered in every-day operations:

(a) Reduce butterfat losses to a point where they do not exceed ½ to 1 percent of the total butterfat purchased.

(b) Improve cottage cheese yield so that it never falls below 16 percent and most of the time in the neighborhood of 16 to 18 percent.

(c) Improve bottle trippage by reducing bottle breakage, etching, etc. Many of us have found during the war that we can obtain good trippage by maintaining deposits on bottles, etc., to the point where it is not unusual to have a trippage of 60 to 70. All future plans for milk plants should give serious thought to the introduction of paper bottles.

(d) Where prices are right, liquid sugar seems to be definitely a "must" for the handling of sweeteners.

(e) Where possible, eliminate the dating of milk and reduce returns to as nearly zero as possible.

(f) Make every attempt to maintain the economies of delivery where market conditions will permit. In many markets there is a definite trend towards not only every-other-day delivery, but three-day delivery with Sundays off. In designing plants, therefore, we should plan for additional raw milk storage and pasteurizing space as well as additional cooler space. Also keep the operations on one floor level where the location will permit.

(g) Centralize storage rooms for bottle milk.

(h) Design ample storage room so that correct loads of materials may be purchased at savings in price of the commodity. In general, the stockroom should be of a size not less than the total square feet of processing room space.

(i) In connection with the glass bottle, adopt the 48-m.m. bottle to reduce cost of caps. The Industry should standardize on either 48 or 51-m.m. if possible.

(j) Limit the number of grades of milk, cream, and other dairy products handled by milk plants. In ice cream plants, the number of flavors should also be reduced.

(k) Wherever possible, reduce the number of special delivery trucks in milk and ice cream plants.

(l) Simplify route bookkeeping to reduce office and delivery expense.

(m) Eliminate dual installation of glass and paper bottles.

(n) Streamline plant operations so as to reduce labor cost and operating expense wherever possible.

(o) It has been shown there is no direct correlation between size and efficiency of plants. Efficiency depends largely upon good management and proper supervision.

THE USE OF THE VACREATOR * IN THE DAIRY FIELD [1]

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HISTORY OF PASTEURIZATION

Louis Pasteur had demonstrated, in 1864, that by heating wine to a temperature of 122° to 140° F. and holding it at this range of temperature for a short time bacteria would be killed and undesirable fermentations would be prevented. He lived to see the beginning, during the last two decades of the 19th century, of the heating of milk and cream on a commercial scale. "Pasteurization" became a neologism throughout the world.

The first commercial pasteurizers were made, in 1880, by Ahlborn, and Fesca, in Germany. During 1885 milk was being pasteurized on a commercial scale in Denmark and in Sweden.

Pasteurization of cream for butter became common, in Denmark, shortly after 1890. Some difficulty had been experienced with the development of an undesirable flavor in the butter made on the estate farm, "Duelund," in 1888. In an attempt to control this condition it was decided to pasteurize the cream before it was made into butter. It was found that the heating process killed the microorganisms which caused the defect, and the undesirable flavor, therefore, did not develop in the butter.

The scientists who introduced pasteurization in the Danish creameries were Fjord, Jensen, and Lunde of the Royal Veterinary and Agricultural College in Copenhagen. Fjord designed a steam-jacketed pasteurizer for flash heating cream. In 1898 pasteurization of cream for butter became compulsory. At first the law specified that the cream should be momentarily heated to a minimum temperature of 185° F., but this was reduced to 176° F. in 1904. Storch, in 1898, perfected a test, based on the effect of heat on the enzyme peroxidase, that would show whether milk or cream had been heated to a temperature of at least 176° F. Pasteurization of skim milk at the creameries, before the milk is returned to the producer, was also made compulsory.

In the United States pasteurization of cream for butter was introduced by H. E. Schuknecht at the Farmers' Cooperative Creamery at Albert Lea, Minnesota. In 1897, or nearly 50 years ago, he found that the process resulted in butter of greater uniformity and superior keeping quality. Mr. Schuknecht found a market in Europe for this new type of butter. Today there is probably not a single creamery of the some 4,000 plants in the United States that is not pasteurizing the cream which is to be used for butter.

In the progressive dairy country of New Zealand pasteurization of milk to be used for butter was first adopted by the Waverley dairy factory during the season 1896-97. Experiments with the pasteurization of cream to be used for butter-making were conducted by the Government for several years following 1897. In 1903 J. Pedersen was appointed dairy instructor, having been imported from Denmark, for the purpose of assisting in the introduction of pasteurization of cream for butter-making. By 1908-09, of the 196 creameries manufacturing butter 20 plants were pasteurizing, using the flash heating method. By 1914 pasteurization was in general use in New Zealand for cream used in the manufacture of butter.

Pasteurization of skim milk and whey, using a flash pasteurizer and a regenerative unit,—being the first equipment of this kind in New Zealand,—was practiced

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* Vacreator is a Trade Mark Reg. U. S. Pat. Off., in Canada and other countries.

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 19, 1946.

by the Whenuakura Dairy Factory in the Taranaki district during the season 1911-12. During the following season this factory was the first in New Zealand to pasteurize milk for cheese. The above-named equipment was used. P. C. H. Petersen was manager and G. H. Wilster was operator of the pasteurizing plant. The milk was heated to a temperature of 160° F. with this equipment. A regulation now requires that all milk used in the manufacture of Cheddar cheese be pasteurized.

Whereas, in United States and Canada a large percentage of the market milk, table cream and ice cream mix is pasteurized, the pasteurization of milk for cheese is not so common. With the development of equipment suitable for the pasteurization of cheese milk, and research on the process, the method is, however, gradually being introduced.

The literature contains numerous reports of tests made to determine the effect of pasteurization on the microorganisms in milk and cream. In Canada and America the research workers Rogers, Berg and Davis; Hammer; Larsen, Fuller, Jones, Gregory and Tolstrup; Hunziker, Spitzer, Mills and Switzer; Hood and White; Macy, Coulter and Combs found, that when using different temperatures and different lengths of holding periods pasteurization was effective in killing 98 to 99.999 percent of the bacteria present in raw cream. With the coil-vat method of pasteurization Wilster and Nielsen found that with 32 lots of cream, using 200 gallons cream for each batch, and pasteurizing at 150° F. for 30 minutes, the number of bacteria in the pasteurized creams ranged from 300 to 60,000. The average bacteria killing efficiency was 99.94 percent. All molds and yeasts were killed.

The phosphatase test, developed by Kay and Graham in England, like that developed earlier by Storch, is a useful presumptive aid in checking milk and cream samples for satisfactory pasteurization.

Although pasteurization first came into use in the dairy industry as a means of extending the life of a dairy product and delaying spoilage, and subsequently was used as an aid in conditioning and preparing milk and its products for conversion, the main and paramount purpose of pasteurization is to protect the consumer from the possibility of infection from pathogens.

The following five methods of pasteurization have been commonly used in United States and Canada:

1. *The Flash Method.* Used to a limited extent for cream for butter. The cream is quickly heated to a temperature of 180° to 190° F. in a steam jacketed container equipped in the interior with a high-speed revolving agitator. The flow of cream is continuous.

2. *The Steam Injection System.* Steam is injected through small orifices directly into the cream passing through a pipe.

3. *The Vat-Holding Method.* Milk, cream, or ice cream mix is heated, by water in a jacket or coil, to the desired temperature. It is then maintained at this temperature for the required period of time.

4. *The High-Temperature Short-Time Method.* Milk or cream is continuously heated by hot water while passing in a thin layer between stainless steel plates, or through tubes, to not less than a minimum temperature of 160° F. Subsequently the product is not permitted to fall below the minimum temperature while passing through a pipe or tube during a period of not less than 15 seconds, before it is cooled.

5. *Heating by Electricity.* The milk is continuously heated between electrodes to a minimum temperature of 160° F. after which it is held for not less than 15 seconds before it passes to the cooling section.

HISTORY AND DEVELOPMENT OF VACREATION

This method of treating dairy products was developed in New Zealand by H. Lamont Murray, the inventor of the Vacreator, and F. S. Board.

When Murray was operating a condensed milk factory in the Waikato district, Auckland Province, New Zealand, he observed that feed flavor, which was common in the milk, was largely eliminated during the condensing process. He, later,

reasoned that if these volatile flavors could be removed from milk while boiling at reduced pressure, without any deleterious effect on the natural flavor or other properties of the milk, a similar method might be employed in the treatment of cream usd in butter-making. Flavors in milk and cream arising from turnips, clovers, spring grass and sundry weeds, consumed by the cows, were common. In 1923 Murray and Board, while operators of the Te Aroha Dairy Company, Ltd., which had an annual output of 4 to 5 million pounds butter, set out to apply this principle to the treatment of cream.

The several stages in the evolution of the process of vacreation were:

1. Continuously passing hot flash pasteurized cream through a vessel under vacuum.
2. Introducing steam into the flow of flash pasteurized cream, on its way to the vacuum chamber so as to obtain steam-distillation.
3. Elimination of the conventional flash pasteurizer by addition of a direct steam contact section to the vacuum chamber, thus obtaining vacuum pasteurization and steam-distillation in the one unit.
4. The addition of a second and high vacuum chamber wherein to obtain further distillation and cooling.

The perfected machine is now extensively used for vacreating cream for butter in New Zealand, Australia and South Africa.

INTRODUCTION OF VACREATION INTO THE UNITED STATES AND CANADA

In 1938 a Vacreator, of a form herein described, the first on the American continent, was installed in the Dairy Products Laboratory at Oregon State College, Corvallis, Oregon. The Murray Company of Auckland, New Zealand, desired to have one or more agricultural experiment stations determine the merits of vacreation of cream for butter before an attempt was made to interest creameries in adopting this method of cream treatment. Machines were later installed at the Iowa Agricultural Experiment Station, Ames, Iowa, and at the University of Manitoba, Winnipeg, Canada.

DESCRIPTION OF VACREATION

Vacreation is a multiple process which consists of (1) pasteurization, (2) steam distillation—evaporation of water—liberation of volatile compounds and gases, (3) distillation, under high vacuum, with further removal of volatile compounds. The temperature of the product is reduced, on account of the high vacuum in the third chamber to about 100° F. before it leaves the machine.

The several phases are integrated and together constitute vacreation.

The Vacreators used for the tests at the three research centers had an hourly pasteurizing (vacreating) capacity of 2500 pounds cream. At present three sizes of Vacreators, constructed of stainless steel and equipped with safety thermal limit temperature controls are available.

The specifications for the machines are as follows:

Capacity, pounds per hour when pasteurizing	2,500 (cream)	5,000 (cream)	15,000 (milk) 12,000 (cream)
Height	6'6"	6'9"	6'6"
Length	3'0"	4'6"	10'6"
Depth	2'10"	3'0"	3'3"
Water required—U. S. gallons per minute	18-24	29-42	35-51
Steam required—pounds per 1,000 pounds cream (less for vacreating milk or mix)	120-160	120-160	120-160
Motor requirements—			
Cream discharge pump	2 h.p.	2 h.p.	3 h.p.
Water pump	3 to 5 h.p.	5 h.p. (2)	7½ h.p.
Shipping weight (without motor)	1,350 lb.	2,000 lb.	3,700 lb.

THE FLOW CYCLE OF THE VACREATOR

The product, fed by the pump X, is admitted by a float control valve to a perforated spray pan located in the top of chamber "A." It falls in droplets from the spray pan and is heated by contact with steam admitted through valve "B." The pressure in the pasteurizing section is below atmospheric and may be held at any desired point, usually between 11 inches and 6 inches of vacuum, thus maintaining any temperature from 190° to 200° F. Lower temperatures may also be used as desired. A spring-actuated equilibrium ball valve "C," is located between the pasteurizing chamber and the next section of the machine. The second chamber "E" and the pipe "D" are kept at a reduced pressure of about 15 to 25 inches of mercury by the action of the ejector condenser "F." The relative pressures in "A" and "E" are controlled by the adjustment of the tension on the equilibrium valve "C."

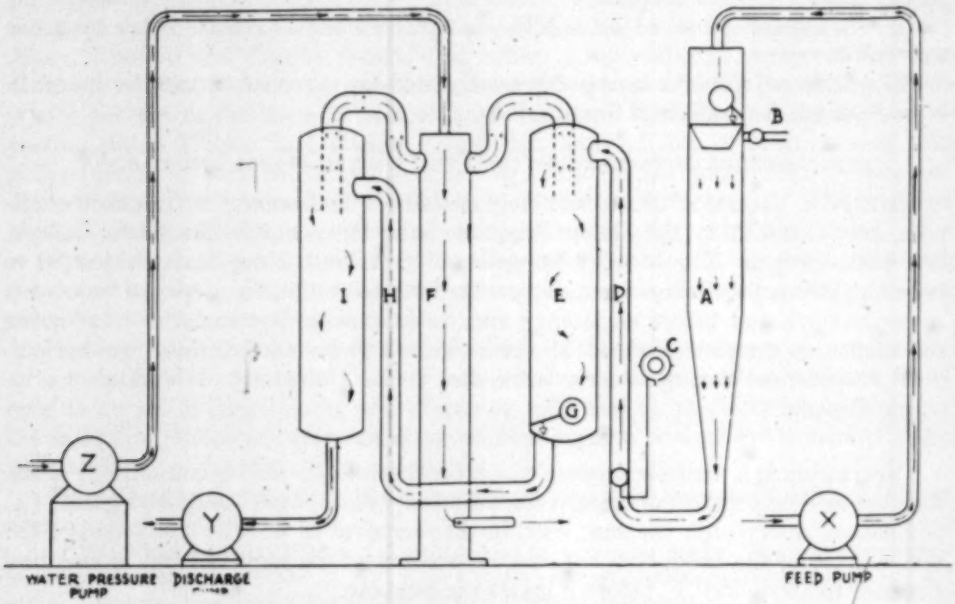

FIG. 1. Diagram illustrating flow cycle of the Vacreator.

The mixture of steam and product, reaching the bottom of the pasteurizing chamber "A," is drawn past the equilibrium valve, passes up the pipe "D" and is discharged tangentially into the cylindrical chamber "E." The product boils in this section at from 160° to 180° F. and releases as water vapor a portion of its water content to the ejector condenser, carrying with it oxygen and volatile substances removed from the product. The intermediate float valve "G" controls the flow of product through pipe "H" into a third chamber "I" of lower pressure, where a still higher vacuum, usually 27½ to 28½ inches, is maintained. The product upon entering this final chamber loses more water vapor and volatile substances and is cooled in the process to about 110° F. The product is pumped from the bottom of the last chamber by a multistage centrifugal pump "Y" and is delivered to the cooler.

The amount of steam passing through valve "B" is in excess of that necessary to raise the product to the pasteurizing temperature. This free steam aids in the freeing and carrying away of dissolved oxygen and certain volatile substances from the products, such as may be imparted by feeds and weeds. The rise in temperature

of the cold water, forced through the ejector condenser by pump "Z," is an indication of the amount of free steam and water vapor thrown off from the hot product in the reduced pressure chambers. If the temperature of the product is approximately 110° F. when it enters the Vacreator and it leaves the machine at 110° F., then the amount of water added by the steam will approximately equal the water lost from the product during the distillation process.

INFLUENCE OF VACREATION ON THE QUALITY OF BUTTER

Tests at the Oregon Agricultural Experiment Station. The investigation extended over one year. In a series of 86 comparisons involving 200 gallon lots, cream of good quality was divided into equal parts. One part was pasteurized by the usual coil vat method (155° F. for 30 minutes) and the other was vacreated. Additional lots of weed-flavored cream and cream of variable quality were also used. The butter was graded weekly by a committee of three or four men. The samples were known by number only and the numbering system was such that the judges obtained no clue through the use of even or uneven numbers or of consecutive numbering regarding the method of pasteurization.

For the 86 comparisons the vacreated-cream butter scored highest 71 times. The average score of the butter from vacreated cream was 92.38 and the average score of that from the vat-pasteurized cream was 91.55. Thus vacreation resulted in increasing the average score 0.83 point. This represents a very remarkable improvement when it is considered that the difference in score between mediocre quality butter and the finest commercial butter is only three points, 93 score being the top commercial grade.

The greatest improvement took place during the spring months. This was due, primarily, to the freeing of feed, weed, and certain loosely bound extraneous flavors from the cream during vacreation.

Butter in 33 comparisons was shipped in 68-pound boxes to Portland for scoring by the Federal butter grader stationed there. Of the butter from vat-pasteurized cream 10 lots scored 92-93 whereas of the butter from vacreated cream 25 lots scored 92-93.

When butter in 79 comparisons was stored at a temperature of 0° to 10° F. for four months, there was a difference of 0.78 point in favor of the average score of the butter made from vacreated cream.

The vacreation method was found to be more efficient in killing bacteria than the vat pasteurization method. In 35 comparisons the geometric average number of bacteria per ml. in the vat-pasteurized cream was 9,284 and in the vacreated cream it was 495.

When cream badly tainted with onion, or with French weed, was used in the experiments the vat method was not effective in removing the undesirable flavor but the vacreation method was effective.

Since these tests were made all butter manufactured in the Oregon State College Dairy Products Laboratory has been made from vacreated cream.

Tests at the University of Manitoba. It was reported that of 153 direct comparisons made in the study between butter made from vat pasteurized and vacreated cream, all but 8, or 145 were in favor of the butter made from vacreated cream on the basis of the flavor scores.

Tests made at the Iowa Agricultural Experiment Station. The results showed that vacreation of good quality cream gave butter of significantly higher score than vat pasteurization of portions of the same cream. There was an average difference of 0.97 point in the score in favor of the butter made from the vacreated cream.

Butter made from fine quality vacreated cream was sent to ten different state and national butter contests. The scores ranged from 93 to 95 points. Although the cream was vacuum pasteurized at a temperature of 190° to 200° F. in the Vacreator no undesirable heated or cooked flavor was present in the butter.

VACREATION OF ICE CREAM MIX

The success with vacreation of cream for butter-making led to speculation as to the merit of the process for treating mix for ice cream, milk for cheese, and milk and cream for consumption as such.

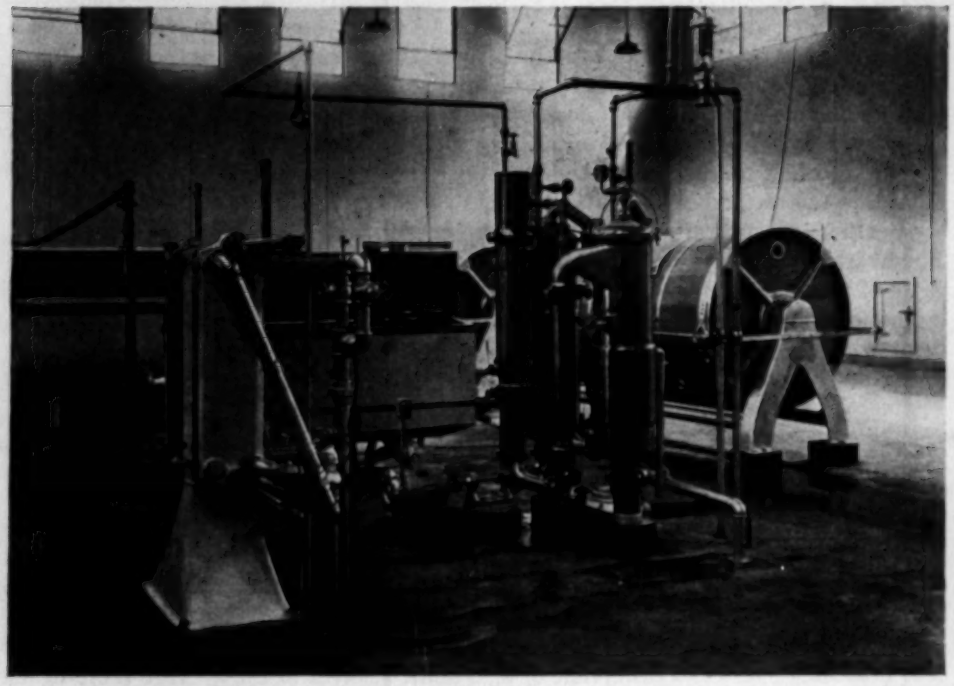

FIG. 2. A typical Vacreator installation in a butter plant.

It was decided at the Oregon Agricultural Experiment Station to first determine the usefulness of vacreation for ice cream mix. It was felt that the continuous treatment of an ice cream mix,—homogenization, pasteurization, cooling,—would be advantageous from a commercial point of view.

During the year 1939 a considerable number of comparisons, involving split batches of mix, were made. It was found that the new method was entirely satisfactory. The flavor of the ice cream was excellent, the bacterial content of the vacreated mix was low, the whipping property of the mix was satisfactory, and the body and texture compared favorably with that of the ice cream made from vat-pasteurized mix.

The new procedure consisted of (1) mixing all the ingredients—cream, milk, dry milk, sugar, whole egg, gelatin—in a mixing vat and heating to 150° F., (2) homogenization, (3) vacreation, using a temperature of 200° F. in the first chamber, (4) final cooling by means of a surface cooler to 35° F.

This method of handling ice cream mix was also studied at the Iowa Agricultural Experiment Station. It was reported that "vacreation of ice cream mix improved the

flavor of ice cream when scored fresh" and "there was less tendency for vacreated mix ice cream to develop a stale, oxidized, or metallic flavor."

Since these tests were made vacreation of ice cream mix has been successfully employed in American and Canadian ice cream factories. The method has become standard procedure in the Oregon State College Dairy Products Laboratory.

VACREATION OF MILK FOR CHEESE

Could vacreation be used satisfactorily for treating milk to be used for cheese manufacture? This problem was next studied at the Oregon Experiment Station. If vacreation would result in a high bacteria-killing efficiency at the temperature employed and if the body and texture of the cheese and curing property were satisfactory the process might be of practical value for several reasons. It would be a continuous method, feed and weed flavor would be eliminated, and the milk would leave the Vacreator at a temperature only about 24 degrees Fahrenheit above the usual setting temperature. The dispersion of fat clumps in the milk by vacreation might also be of value in reducing the fat loss in the whey and in preventing fat pockets from forming in the cheese.

The preliminary tests showed that it was necessary to preheat the milk to a temperature of 145° F. in a continuous heater and to increase the temperature to 165° F. in the Vacreator in order to inactivate the enzyme lipase.

The experiments were interrupted by the war. Only 12 batches of milk were used in the tests. The Federal grader at Portland graded the raw-milk Cheddar cheese an average of 89.87 points and the vacreated-milk cheese 90.92 points.

Three cheese manufacturing plants located in southeastern states are now satisfactorily vacreating milk used in the manufacture of Cheddar cheese. The milk is preheated to 145° F. and is then instantaneously heated to between 165° and 175° F. in the Vacreator.

When it is desired to make Roquefort type cheese, instead of using a forewarming temperature of 145° F. a temperature of 110° F. may be used, followed by heating in the Vacreator from 165° to 170° F. This treatment increases the lipolytic activity. It was shown earlier by Hammer and Lane in work at the Iowa Agricultural Experiment Station that homogenization of raw-milk for blue cheese activated the enzyme lipase and this resulted in a shorter curing time. The hydrolysis of the fat and the production of typical flavor and desirable body and texture of the cheese were accelerated.

Fabricius and Nielsen of the Iowa Station found that vacreation had the same beneficial effect that was obtained by homogenization. Roquefort type cheese made from vacreated milk was pronounced fine by connoisseurs of this most excellent cheese.

CONDENSING MILK WITH THE VACREATOR

Although Lamont Murray conceived the idea of pasteurizing cream under a partial vacuum, as a result of his experience in the milk condensing business, he designed the Vacreator for the specific purpose of (1) pasteurization, (2) volatile feed flavor removal by steam distillation, and (3) partial cooling. Wilster began experimentation and tests with the Vacreator with the view of condensing milk or ice cream mix. If the machine could be economically and satisfactorily used for this purpose this would be quite advantageous to ice cream plants owning Vacreators as they would be able to remove water from locally obtained products.

When the scarcity of milk solids for ice cream manufacture developed in 1942 it was decided to activate a project at the Oregon Agricultural Experiment Station on condensing milk, or ice cream mix with the Vacreator. At first the tests were

unsuccessful and it seemed almost impossible to remove enough water from skim milk to make the process practical. In the first trials the skim milk, pumped to the Vacreator at a temperature of 150° F. would not even go through the machine; it became flooded and the milk went into the condensing water. No steam was applied to the Vacreator. After much experimentation the following method resulted in a very satisfactory and convenient procedure of condensing milk with the Vacreator:

1. Pump the milk through a continuous preheater and heat it to 200°-205° F.
2. With the equilibrium valve removed maintain a vacuum of 24 to 25 inches in the second chamber and a vacuum of 27½ to 28 inches in the third chamber. Use no steam.
3. Allow the hot milk to enter the first chamber through the float valve.

With a rate of flow of milk of 5000 pounds per hour approximately 500 pounds water can be removed per hour with the "Baby" Vacreator.

With a rate of flow of milk of 12,000 pounds per hour approximately 900 to 1000 pounds water can be removed per hour with the "Junior" Vacreator.

The milk will leave the Vacreator at a temperature of approximately 110° F. About 45 minutes condensing with the "Baby" Vacreator is required in order to remove sufficient water from milk to give a condensed product of the proper density for a 900 lb. ice cream mix of standard composition. Immediately after condensing the milk the cream, sugar, gelatin, etc. are added to the condensed milk and the complete mix can then be homogenized, vacreated and cooled. The condensed milk will have a fine flavor, free from any cooked character.

Whole milk can also be satisfactorily condensed.

The complete milk, cream, sugar, gelatin mixture can also be condensed, but it is considered more practical to first condense the milk.

In the tests made in Oregon and also in a commercial ice cream factory in Pennsylvania ice cream of an excellent quality was obtained from vacreated ice cream mix with which Vacreator condensed milk was used. The cost of condensing milk by this method was found to be reasonable.

Additional experiments involving the use of the Vacreator for condensing buttermilk, whey, chocolate milk and for removing water from other dairy products are contemplated.

SUMMARY

In summarizing, it can be stated that the Vacreator may be used in dairy plants for the purpose of continuous quick-time pasteurization of milk for cheese, cream for butter and ice cream mix; for the elimination of feed and weed flavor and other loosely bound flavors; and for the partial cooling of the product before it leaves the machine. It may also be used for condensing milk for ice cream mix and for condensing miscellaneous fluid dairy products.

Vacreation appears to cause little chemical change in the milk, cream or ice cream mix. This is evidenced by: the absence of cooked, or scorched flavor in the vacreated product; the superior keeping property of ice cream; the less severity on certain milk enzymes; the work of Wulzen who found that the factor which prevents the development of stiffness in the joints of guinea pigs was destroyed by pasteurization of cream exposed to the atmosphere, but was not destroyed when the cream was vacreated; and the superior keeping property of butter made from vacreated cream when held in storage for four months at 0° to 10° F. As the recent research by Sharp, Guthrie and Hand showed that the development of oxidized flavor and the destruction of vitamin C in pasteurized milk could be prevented by the removal of oxygen from the milk at the time of pasteurization, it would be expected that vacreation, because of its deaerating effect, would have a similar protective action. Results from research on this latter point have not yet been published.

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OUR NEWER KNOWLEDGE REGARDING THE MANUFACTURE OF POWDERED WHOLE MILK[1]

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The manufacture of dry whole milk was confined to a very few concerns prior to World War II. Results of their experience and research were in part made available to others to aid in meeting the needs of the armed services. Extensive research in industrial and institutional laboratories has today greatly extended the available knowledge.

Research in dry whole milk has been directed primarily toward reducing the extent of flavor deterioration during storage, and to a lesser degree to the production of a product which from a physical standpoint may more easily be reconstituted to yield an acceptable replacement for fluid milk. Dry whole milk is subject to two types of flavor deterioration: (1) fat oxidation resulting eventually in a tallowy flavor, and (2) the development of a stale flavor, the exact origin of which still is not entirely known. In exceptional circumstances other changes notably, hydrolytic rancidity, a loss in solubility and browning may occur in storage.

Oxidation of the fat may be controlled with certainty only by the essential elimination of atmospheric oxygen from the system. Antioxidants, including those originally present in the milk, produced in the milk during processing or added to the milk, retard fat oxidation. The elimination of added metallic catalysts, especially copper, may be considered as essential. Dry whole milk gradually utilizes oxygen from the surrounding atmosphere. In air-packed powder, this progresses as shown by Mattick et al. *(13)* and Hetrick and Tracy *(8)* at an increasing rate after the induction period of the fat is past. The oxygen is exhausted in adequately gas-packed powder before material uptake of the oxygen by the fat can occur. Oxygen also is utilized by constituents of the milk other than fat. Among these, although accounting for only a small amount of oxygen, is ascorbic acid, which in dry whole milk gradually decreases in the presence of oxygen. The amount of the decrease is slight in adequately gas-packed powder, and retention is good even in air-packed powder. All of the ascorbic acid may be lost if the powder becomes tallowy.

In common with other dehydrated foods containing proteins and a reducing sugar, the Maillard reaction occurs in dry milk. Accompanying the browning are a decrease in solubility, increase in acidity, evolution of carbon dioxide, an increase in reducing substances reducing potassium ferricyanide, Chapman & McFarlane *(2)*, and an increase in fluorescence of a 10 percent KCl extract of the protein residue following extraction of the dry milk with acetone and ether. Almost certainly all of these changes do not result from the same reaction. Data secured in our laboratory indicate that the rate of browning itself is independent of the oxygen content. Carbon dioxide production is accelerated by increase in the oxygen content, but may occur in the absence of oxygen. All of these changes, however, are accelerated by increases in the moisture level and in temperature. The presence of moisture appears to be essential for the Maillard reaction.

The relationship of these changes to the stale flavor or flavors is uncertain. The rate of staling is accelerated by increases in moisture, oxygen and temperature. That

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 19, 1946.

a low moisture level retarded staling and browning has been known in the dry milk industry for many years and is now recognized to be true for dehydrated foods in general.

Edwards and Dutton *(5)*, working with dehydrated whole egg powder, concentrated a brown material found in both the total ether extract and the cephalin fraction. Their evidence indicates that this material was formed from the reaction of a cephalin amino group with aldehydes. A relationship between this reaction and the staling of dried eggs was suggested. A reaction of this type would be possible in dry whole milk. We have noted an increase in the fluorescence of an ether extract of dry whole milk, particularly at higher moisture levels. Dahle and Josephson *(4)* prepared a dry milk product from supercentrifuged skimmilk and butteroil. Air-packed dry milk prepared in this way was reported to keep materially better than the normal product presumably due to a reduction in the phospholipid materials present. Working with adequately gas-packed powder, we have not been able to verify this finding. Much research is yet needed on the cause and prevention of the staling of dry milk.

The following factors are considered in choosing an acceptable manufacturing procedure for dry whole milk:

1. THE QUALITY OF THE MILK

The keeping quality of dry whole milk at one time was considered to be influenced greatly by the freshness and quality of the fluid milk supply. High quality milk both from a flavor and bacteriological standpoint still is desirable; however, both experimental evidence and practical experience have shown that dry whole milk of satisfactory keeping quality can be made from any good commercial milk. The data of Mattick and associates *(13)* are especially interesting in this regard. Air-packed dry whole milk made from a selected milk supply kept significantly better than that from an ordinary milk supply when the fluid milk was preheated to 165° F. before drying. Very little, if any, difference in keeping quality was noted, however, when a preheating temperature of 190° F. was used.

2. PREHEATING TEMPERATURE

The fact that the keeping quality of dry whole milk was improved by preheating the fluid milk to a temperature considerably above that considered normal for pasteurization (145° F. for 30 minutes or 160° F. for 15 sec.) was first shown by Holm, Greenbank and Deysher *(11)*. This effect is now generally attributed to the production by the heat treatment of sulphydryl groups which act as antioxidants in the resulting powder. The production of sulphydryl groups during heating is a function both of temperature and time. Loss of sulphydryl groups through volatilization may occur. The lack of a satisfactory specific analytical method for the sulphydryl groups has delayed a complete evaluation of this factor. The present trend in commercial practice is to preheat the fluid milk at temperatures ranging from 190° to 220° F. or slightly higher. The holding period at the preheating temperature may vary from a few seconds at the higher temperatures to as long as 30 minutes at the lower temperatures.

The need for high preheating temperatures to retard fat oxidation is greatly minimized by adequate gas-packing. In fact, some in the industry prefer to use preheating temperatures no higher than 165° F., thus avoiding a definite cooked flavor in the dry whole milk, and to rely on adequate gas-packing to prevent tallowiness. A high preheating temperature is effective, however, in retarding the rate of

flavor deterioration and loss of ascorbic acid after the seal has been broken and also in milk after reconstitution, Mattick et al. *(13)*.

There has been some speculation as to whether the temperature to which the fluid milk was preheated influenced the rate of development of the stale flavor. Trials in our laboratory involving heat treatments ranging in 10° F. intervals from 150° F. for 30 minutes to 240° F. for 20 minutes indicate that in gas-packed powder the stale flavor appeared at the same age and developed to the same intensity regardless of the preheating temperature.

3. CLARIFICATION

Holm, Greenbank and Deysher *(11)* in 1926 indicated that clarification of the milk improved the keeping quality of the powder. Later work has failed to verify this observation. Mattick et al. *(13)*, found the keeping quality of air-packed dry whole milk unaffected by clarification of the milk.

An analagous practice is that used commercially in some plants of separating the milk, processing the cream and skimmilk separately and recombining them just before drying. Extensive trials with this practice in our laboratories have indicated that the keeping quality of the resulting powder is the same as that made from normally processed milk.

4. HOMOGENIZATION

Assuming that the preheating has been sufficient to inactivate lipolytic enzymes, homogenization of the milk prior to drying is of significance only to the extent to which it influences the reconstitution of the milk. Unsightly film formation on the glass or other containers of reconstituted milk is a frequent cause of criticism. With many samples of milk, the film is due in large part to small butter granules resulting from partial churning. The degree of churning can, of course, be decreased by adequate homogenization.

5. THE DRYING OPERATION

A. *Moisture Level.* The moisture content of the powder is one of the most important factors influencing the keeping quality. This was shown by Holm and Greenbank *(10)* as early as 1923. With air-packed powder, either excessively low or high moisture levels are detrimental to the keeping quality. These workers set the optimum level for spray-dried whole milk at about 3.0 percent. Oxidation of the fat is accelerated at abnormally low oxygen levels. György, Stiller and Williamson *(7)* have presented some data which indicate that this is because the sulphydryls are ineffective as antioxidants in the absence of some moisture. In gas-packed powder, which is protected from oxidation by the essential absence of oxygen, low moisture levels do not promote the development of tallowiness.

As noted previously, the staling of dry whole milk is accelerated by increase in the moisture level. Present QMC specifications call for not more than 2.50 percent moisture in extra grade spray powder and not more than 2.25 percent in premium grade powder. Extensive trials by Sharp *(14)* and also in our laboratories indicate that there is little improvement in the keeping quality of the powder by reducing the moisture content below 2.25 percent. Staling has been noted in powders even at moisture levels as low as 0.25 percent. Since the vapor pressure of spray-dried whole milk with a moisture content of 2.25 percent is about 1.0 mm. Hg at room temperature, a significantly lower moisture content is difficult to attain commercially, and does not appear to be of material advantage. Moisture levels above about 2.5 percent are, however, objectionable. Dry whole milk is highly hygroscopic and its low vapor pressure is evidence of the need for a vapor-proof package.

B. *Solubility of the Powder.* The degree of solubility of the resulting powder is influenced by many variables including the concentration of the milk sprayed, the size of the spray particle, and the temperature, humidity and velocity of the air streams. The many factors involved in drier operation must be integrated to yield a product in which protein destabilization has been minimized. Unsightly film formation on the glass or other containers of reconstituted milk involves at least the two factors of degree of churning and extent of protein destabilization.

C. *Cooling the Powder.* The desirability of removing the powder from the drying chamber and cooling it promptly has been a subject of some argument. Without continuous removal the powder may be exposed to the temperature of the drying chamber for up to 20 hours. Even after removing from the drier the rate of cooling will be very slow if the powder is packed in barrels. The fact that dry whole milk of acceptable keeping quality is produced in batch-operated driers as well as in driers providing continuous removal is proof enough that prompt cooling of the dry whole milk is not greatly advantageous. Based on our own observations, however, continued exposure of the powder to the temperature of the drier intensifies the cooked flavor of the milk, and accelerates changes which at least are associated with the stale flavor. Within 24 hours at 140° F. measurable amounts of carbon dioxide are produced, the reducing substances reducing ferricyanide increased and the fluorescence of the protein fraction increased. The desirability of reasonably prompt cooling of the powder is indicated.

6. GAS-PACKING

Although air-packed dry whole milk may not acquire a tallowy flavor even after many months' storage, the keeping quality is markedly improved by adequate gas-packing. Current Q.M.C. specifications call for an oxygen content not exceeding 3 percent of the gases in the can. This is approximately equivalent in a normal pack to 3.0 ml. of oxygen per 100 grams of powder. Lea, Moran and Smith *(12)* have noted a definite improvement in the keeping quality of the powder at lower oxygen levels and indicated that 1.0 ml. of oxygen per 100 grams of powder was a desirable objective. Similar results have been reported by Hetrick and Tracy *(8)* and have been observed in our laboratory.

Since the spray-dried milk particles entrap bubbles of air or foam during the drying process which may be equivalent to as much as 4 or 5 ml. of oxygen per 100 grams of powder, the gas-packing of dry whole milk presents a special problem. The lactose glass constituting the continuous phase of the spray-dried milk particle, and thus the walls of the air cells, does not rupture due to internal pressure during evacuation. Consequently, upon simple evacuation and gassing with nitrogen or carbon dioxide, most of the oxygen in the air cells is left in the powder. This occluded oxygen slowly diffuses from the air cells to equalize the oxygen pressure. The diffusion occurs at such rates characteristic for each powder that the logarithm of concentration is inversely proportional to the logarithm of time. Equilibrium usually is reached in 7 days or less. The final equilibrium oxygen level is determined by the completeness of evacuation, the oxygen content of the nitrogen used and the amount of the entrapped air. Evacuation pressures below 10 mm. of Hg. reduce the final oxygen level only slightly.

Since the oxygen diffuses from the air cells with time, this phenomenon may be utilized to reduce the oxygen content of the final package. Three methods are in common use:

1. Holding the powder in bulk under a vacuum. This may be done either in drums or in large tanks. Although equilibrium of the oxygen content between the air cells and the atmosphere surrounding the powder particles is not attained until

5 to 7 days, sufficient diffusion will have occurred in 24 hours so that if the vacuum is then broken either with air or nitrogen, the powder canned and immediately vacuumized and gassed, final equilibrium oxygen levels of 1 to 2 percent may be reached.

2. Double gassing. In this method the unsealed cans of powder are evacuated, gassed and sealed. After a suitable time interval the seal is broken, the cans re-evacuated, gassed and resealed. Since the difference between the partial pressures of the oxygen in the air cells and in the surrounding atmosphere determines the rate of diffusion in a given powder, this method provides the same effectiveness as vacuum holding.

3. Use of dry ice. The addition of 3 to 5 pounds of dry ice to a drum of powder results in the replacement of most of the free air in the drum with carbon dioxide. The same principle is involved as in the other methods; however, the results are subject to greater fluctuation since the removal of the oxygen from the container is less positive.

Such factors as the solids content of the milk dried, the method of atomizing, whether centrifugal, two fluid or pressure spray, and in the case of pressure spraying, the size of the nozzle orifice and the spraying pressure as well as the presence of foam in the milk sprayed, influence the amount of air entrapped in the powder particles. By proper application of the above methods, however, the oxygen content of the canned powder may be reduced to 2.0 ml. or less per 100 grams of powder.

Through the years the suggestion that milk be dried in an atmosphere of nitrogen or carbon dioxide has frequently been made. We have experimented extensively with drying in an atmosphere of nitrogen or carbon dioxide and have developed equipment which makes this procedure entirely practical. Although the trials still are in progress, the results indicate that the quality and keeping quality of the resulting powder is essentially the same as air-dried powder gas-packed to an equivalent oxygen content. However, oxygen levels as low as 0.5 ml. of oxygen per 100 grams of powder may easily be attained by drying in commercial nitrogen or carbon dioxide. A level this low may be secured in air-dried powder only by prolonged vacuum holding prior to final packaging, evacuating and gassing, or by triple gassing, allowing at least 24 hours between each evacuating and gassing. Powder containing not more than 2.25 percent moisture which was either dried and canned in nitrogen or carbon dioxide or gas-packed to an oxygen level of 0.5 ml. of oxygen per 100 grams of powder keeps very well even at storage temperatures as high as 110° F. The powder develops a slight stale flavor after a month or two, but undergoes very little further change in flavor at least for periods in excess of 18 months, which is the present limit of our trials.

7. USE OF ANTIOXIDANTS

In common with many other fat-containing foods, fat oxidation in air-packed dry whole milk may be delayed by the addition of suitable antioxidants. Among those which have been shown to be effective are: wheat germ oil *(1)*, *(15)*; nor dihydroguaiaretic acid *(3)*; gum guaiac *(9)*; ascorbic acid *(9)*; and ethyl gallate *(6)*. Antioxidants do not increase the shelf-life of adequately gas-packed powder.

Even though produced utilizing the best of present knowledge, dry whole milk still is not an ideal product. It is a satisfactory yet not perfect replacement for fluid milk. It may be almost perfectly dispersible in, but it is not readily miscible with, water. The film formation on containers of the reconstituted milk is objected to by many users. Probably its greatest fault is the stale flavor which develops during storage. There still is need for research.

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WASTE DISPOSAL IN FOOD PLANTS

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The increasing demand for freedom from pollution in streams and lakes is focusing attention on methods for the disposal of wastes from industries.

Commercial utilization has been extensively practiced in the preparation of ensilage from pea and corn wastes, of dehydrated animal feed and molasses from citrus wastes, of sweet and bitter oils from apricot kernels and of various by-products from apple wastes. To a lesser extent, tomato and cranberry wastes are being utilized.

The treatment of liquid wastes from food processing plants is frequently necessary to prevent stream pollution. The methods in general use are:

1. Screening through fine-mesh mechanically operated units. This pretreatment is required regardless of any further type of treatment. Screening may constitute adequate treatment where sufficient stream is available.

2. Chemical precipitation is satisfactory with certain types of food wastes but is limited to removal of suspended and colloidal solids.

3. Discharge to a municipal treatment plant. Pretreatment by chemical treatment or adjustment of pH to insure arrival of wastes in a fresh condition may be required.

4. Soil absorption may be utilized with the proper types of soil.

5. Lagoons are increasing in popularity as a means of excluding wastes from streams in areas where soil absorption cannot be employed. Odor control can be maintained by means of nitrate of soda.

A bibliography follows the article.

The amount of waste, both solid and liquid, produced during the manufacture of canned, frozen, dehydrated, or preserved foods is frequently enormous. Consisting as they do largely of carbohydrate material from fruits and vegetables, these wastes rapidly undergo decomposition and if discharged into a receiving body of water may result in pollution. Public demand for streams and lakes suitable for fishing, bathing and other recreational purposes and as sources for industrial and municipal water supplies, has resulted in legislation designed to protect these natural sources of water. As industries multiply and cities increase in population, additional quantities of waste are being discharged. Insofar as the previously mentioned food industries are concerned, the situation is aggravated by the fact that their activities are concentrated largely in the summer months—a time during which streams and lakes are least able to assume an added burden. High temperatures, low stream flows and active biological life all tend to reduce the amount of dissolved oxygen available for oxidation of organic material from food plants. The maintenance of 3 p.p.m. and preferably 5 p.p.m. of dissolved oxygen is necessary to support fish life.

The methods available for the disposal of solid waste and liquid waste are entirely different. It is therefore necessary to collect the two types of waste separately within the factory insofar as is possible, or to separate them by screening when the two are combined. The separate collection of solid waste has several advantages. When so collected, solid wastes are drier, an important consideration when solids are dried for animal feed. Solid wastes free from adhering water are easier to handle and do not require water-tight compartments when disposed of by hauling away. Suitable metal containers, chutes, or conveyors should be provided to collect or convey solid wastes. The method of conveying solid wastes by means of fluming should be discontinued. Every effort should be made to prevent solids from enter-

ing factory drains. The presence of a large amount of solid material may overload the screening unit, but most important is the fact that the pollutional strength of the liquid waste is increased by solution of soluble organic material and by a greater amount of finely divided solids not removable by screening. Solid wastes are sometimes dewatered by means of a tomato cyclone. The liquid discharged from the cyclone has a pollutional value many times as great as normal factory waste water. It should not be added to other factory waters if any disposal problem exists. Its relatively low volume permits hauling by tank wagon but a more practical solution consists in the discontinuance of dewatering. Since the disposal of liquid waste is generally more difficult and expensive, why increase its strength by undesirable practices which can be avoided?

The recovery of usable by-products from fruit and vegetable processing plants is an enticing proposition. That utilization has not been practiced much more extensively is owing to: (1) the seasonal nature of fruit and vegetable crops; (2) the perishable nature of the waste which requires immediate conversion; (3) reluctance of food processors to assume additional responsibilities during their intensive operating periods; and (4) the fact that the financial return is comparatively small since the by-products produced enter highly competitive markets. Most of these objections could be met by establishing separate waste utilization plants centrally located within economical hauling distances from several food processing plants and operated in conjunction with other agricultural products. Alfalfa driers, for example, could dry many vegetable wastes for feed purposes. The percentage of solid waste material from a few typical vegetable and fruit processing plants will serve to illustrate the quantity of waste which must be disposed of; for example, beets, cabbage, and tomatoes, 25 percent; asparagus, peaches, pears, and spinach, approximately 40 percent; apples and carrots, 35 percent; grapefruit, 58 percent; peas, 79 percent, and corn, 86 percent.

Pea waste, to the amount of approximately one and one-half million tons, is produced by the canning and freezing industry. The bulk of this material is stacked for use as cattle feed. Approximately 30 percent of the stacked weight is lost as seepage of soluble constituents and wastage of the outer portions of the stack which are unsuitable for feed. The quality of pea ensilage is quite variable. Peterson reports from 0 to 130 micrograms of carotene per gram of pea ensilage. The University of Delaware Agricultural Experiment Station has reported some preliminary work on the preparation of pea leaf and other vegetable leaf meals. Further work along this line is indicated.

The utilization of tomato waste would be of particular interest to canners. A few canners are preparing a dried tomato refuse product for use in chicken feed. Considering the quantity of tomato waste produced and the expense involved in disposing of a very sloppy material, greater by-product recovery may be expected when inexpensive drying units are available.

The Western Regional Research Laboratory and the College of Agriculture of the University of California have given attention to the possibilities of utilizing asparagus waste. A number of lines of investigation have been pursued, including feeds, fertilizers, fiber board, paper, utilization of expressed juice for soup stock in both the liquid and powdered form and vacuum-concentrated juice as a nutrient for penicillin mold culture. The greatest concentration of efforts toward the utilization of wastes incident to farm production and commercial processing of vegetable foods is being conducted by the Eastern Regional Research Laboratory. Methods of production of vegetable leaf meals, their composition, utilization for animal and

poultry feeds, and as raw materials for the extraction of carotene, tocopherol and xanthophyll are subjects of investigation. Sometimes rather unusual uses for waste materials are discovered. For example, in certain areas the lack of coloring in the yolk of eggs laid during the winter months is of importance to poultrymen. The addition of dried pimento waste to hen-laying mash has been recommended by the Georgia Experiment Station to secure the desired egg yolk color.

Among the fruits, apple wastes, including culls, are extensively utilized in the manufacture of vinegar, powdered pectin, pectin concentrate, jelly stock and apple syrup. A number of uses for pits from apricots, peaches and cherries have been proposed. Commercially, only the kernel from apricot pits is of importance as raw material for the manufacture of sweet and bitter oils for use in the food, pharmaceutical and cosmetic industries.

Nealy has reported on the utilization of cranberry waste from which six products with commercial possibilities have been recovered. Ursolic acid, cranberry wax, and cranberry oil have been recovered on a limited scale. It is estimated that complete recovery could add $1,000,000 annually to the value of the cranberry crop. The residue after removal of wax and ursolic acid has found a ready market as a filler for plastics and as a substitute for wood meal.

The U. S. Citrus Products Station at Winter Haven, Florida, and others have undertaken studies on the utilization of citrus wastes. A number of commercial recovery plants are in operation utilizing for the most part grapefruit waste. Dried cattle feed, pectin, peel oil, and molasses are the principal by-products. Conversion of the more concentrated liquid wastes from by-product recovery to molasses for alcohol production, effectively disposes of a waste having a very high biochemical oxygen demand.

The list of possible by-products from fruit and vegetable wastes comprises many products. A greater conversion of waste materials can be realized only after further investigations provide new markets for known by-products or results in the discovery of new by-products, all of which must be produced economically. This is, indeed, a challenge to both the agricultural research chemist and engineer and to industry. In the meanwhile, much material will remain a waste to be hauled away at considerable expense and treated as garbage.

The disposal of liquid wastes generally presents the most critical disposal problem to food processors. Large volumes of water are used to wash fruits and vegetables and to maintain sanitary conditions in the plant. Some form of treatment is generally necessary or will be demanded as anti-pollution laws are enforced. In order to properly appraise the situation the following data should be obtained: volume and characteristics of each type of waste water produced, degree of treatment required, area and topography of land available for treatment plant, possibilities of utilizing local municipal treatment works if any exist or are contemplated, and financial considerations. Consideration must be given to the fact that most food processors of the type being considered operate on a seasonal basis, which does not justify the capital expenditure for treatment that could be borne by a plant operating throughout the year. After obtaining the basic information with regard to the waste, treatment by one or a combination of the following methods can be considered: screening, chemical precipitation, biological filtration, discharge to a municipal treatment plant, land absorption or discharge to an impounding lagoon.

Efficient screening of all liquid wastes carrying any screenable organic material is essential, regardless of any further treatment which may be necessary. This fact has been stressed time after time by all authorities, but too often complete screening

has been neglected. After installation, screening units must be properly operated and maintained. On more than one occasion, failure to screen or to screen properly has resulted in troubles which otherwise would not have occurred either in receiving bodies of water or at municipal treatment plants receiving the waste. Mechanically operated screens of either the rotating or vibrating type should be used. Studies conducted by the New York State Board of Health indicate that wastes may be screened at a rate not exceeding 3.5 gallons per square foot of screen per minute in rotating screen units carrying a 40-mesh wire screen. A variety of wastes have been successfully handled in vibrating screen units equipped with 40-mesh wire screen at rates varying from 32 to 70 gallons per square foot per minute. The use of stationary screens alone cannot constitute adequate screening. If constructed of 40-mesh screen they quickly become clogged. If the wire cloth has openings large enough to permit a free flow only the coarser solids can be retained. Stationary screens installed after mechanical screening provide a factor of safety in the event of operating difficulties at the primary screening unit.

Chemical coagulants may be used to further reduce the strength of screened wastes. Lime followed by either ferrous sulfate or alum is generally used in this type of treatment plant operated by food processors. If properly conducted, chemical treatment will remove suspended and colloidal solids but not such materials as sugars which are in true solution. The degree of treatment will therefore depend upon the relative proportion of suspended and colloidal solids to soluble organic solids. In general, chemical precipitation removes in the order of 50 percent of the pollutional material. Two types of chemical treatment plants are in use, the continuous-flow and the fill-and-draw or batch treatment. Lack of flexibility in maintaining optimum chemical dosage rates and inability to remove completely the large volume of sludge produced limit the efficiency of continuous-flow treatment. These difficulties have been eliminated by the fill-and-draw treatment which, however, is somewhat more expensive in construction and operating costs. Briefly, this method involves pumping screened waste to one of several treatment tanks where the coagulants are added and flocculation obtained. The operator is able to judge by appearance whether additional coagulants are required. The floc is allowed to settle and the clear supernatant liquid discharged through a floating pipe. Sludge is discharged to sludge-drying beds. During the treatment, settling and discharge periods raw waste is pumped into a second treatment tank and the cycle repeated. Chemical precipitation has proved satisfactory where stream dilution has been sufficient to absorb the residual biochemical oxygen demand and also as a means of pretreatment prior to discharge to a municipal treatment plant.

Biological filtration on the scale necessary for a high degree of treatment of strong factory wastes can well be prohibitive in cost for the seasonal food processor. The large initial investment can be reduced somewhat by the use of high rate filters with recirculation but only at the expense of additional operating costs. Any type of biological filter not in continuous use must be conditioned before reaching maximum efficiency. This means either that the filter is operated for several weeks inefficiently or that the filter must be artificially conditioned prior to use. Some fruit and vegetable wastes may be deficient in mineral nutrients, particularly nitrogen, required to maintain an active biological growth in the filter. Most of the available information on biological filters operating solely on fruit and vegetable wastes has been derived from experimental units. While such data indicates that biological filters are capable of a high degree of treatment, the installation of filters should be considered only as a last resort.

The treatment of food wastes at municipal treatment plants is an ideal solution when the city plant has sufficient capacity to handle the added volume and pollutional load. Before discharge to the municipal plant the waste should be screened. The presence of excessive amounts of fruit and vegetable solids frequently overloads digestor capacity. As previously indicated, pretreatment by chemical precipitation is sometimes required. With untreated waste it may be necessary to add lime to counteract acid formation; otherwise, septic conditions may lower treatment efficiency. In some cases it has been found advantageous to provide temporary storage of wastes in an impounding lagoon from which the waste is discharged to the municipal plant at a uniform rate. Treatment of the impounded waste with sodium nitrate has been found to be necessary to control odors. Municipal treatment plants of both the biological filtration and activated sludge types are successfully treating food processing wastes. The financial arrangement between industry and the municipality is, in the last analysis, the determining factor.

Screened wastes may be disposed of by soil absorption in localities where soil conditions will permit rapid absorption. Several methods of application are in use. In one, furrows approximately 24 inches wide at the top, 15 inches wide at the bottom, and 9 inches deep act as receiving channels for distribution of the waste over the field. Ridges between furrows should be about 3 feet wide. Preliminary tests are necessary to determine the field area required. Local ponding must be prevented to avoid excessive odor formation. With any type of soil absorption or storage lagoons precaution must be observed to prevent underground seepage from polluting wells.

Impounding of wastes in lagoons is practiced by many industries. Until recent years, the use of lagoons by food processors has been limited by the ability to secure isolated lagoon sites where odors would not create a nuisance. Insofar as the canning industry is concerned practically all of the waste treatment plants installed during the past four years have been lagoons treated with sodium nitrate to control odor formation. Sodium nitrate will eliminate or reduce lagoon odors according to the amount of nitrate added. The function of sodium nitrate is threefold: (1) to furnish oxygen available for aerobic bacterial decomposition, (2) to stimulate the growth of chlorophyllaceous organisms which in turn produce additional oxygen by photosynthesis, and (3) to maintain an alkaline reaction. Strong carbohydrate wastes undergoing bacterial decomposition create an oxygen demand greatly in excess of that which can be supplied through natural aeration. As a consequence, anaerobic decomposition predominates, with the production of offensive odors. Sodium nitrate by directly and indirectly supplying oxygen promotes nearly odorless aerobic decomposition. Economically, it is not feasible to satisfy completely the oxygen demand of the waste. In practice it has been found possible to add an amount sufficient to satisfy approximately 20 percent of the 5-day biological oxygen demand when the waste is held in shallow lagoons.

If topographic features permit, it is preferable to construct a single large lagoon rather than several small ones. It requires about two weeks to establish in the lagoon the desired growth of aquatic plant and animal life. Once established they act quickly upon incoming fresh waste. With several lagoons operated in parallel it is necessary to repeat this critical growth cycle. The operation of two or more lagoons in series, that is, as flowing-through lagoons is also undesirable. The first lagoon continually receives strong, fresh waste and does not receive the dilution and other beneficial effects of the waste contained in the lower lagoons. A single lagoon partially filled with nitrate-treated waste from one period of canning is most effective

in treating the waste from subsequent canning periods and permits considerable saving in the amount of sodium nitrate required for later packs.

A large shallow lagoon rather than a small deep one is recommended, not only because of better natural aeration, but because the stimulating effect of sunlight on biological life within the lagoon is effective on a larger proportion of the waste. If sufficient land is available, a liquid depth of about 3 feet is suggested. A depth of 5 feet is the maximum which should be used. The lagoon should be constructed to accommodate a volume one-fourth larger than the total seasonal volume of waste produced, so that this volume of stabilized waste may be retained in the lagoon for: (1) diluting the next year's addition of strong waste; (2) seeding these fresh wastes with suitable organisms retained from the previous year, and (3) preventing weed growth in the lagoon.

The performance of two lagoons, one with and the other without sodium nitrate treatment, is of interest. Both received pea and corn waste from canning operations. The nitrate-treated lagoon during the period of June 25 to July 20 received pea waste having a 5-day biochemical oxygen demand of approximately 2,000 p.p.m. On August 16 corn waste was admitted by which time the biochemical oxygen demand of the waste in the lagoon had been reduced to 156 p.p.m. The pH was 8.6. Corn canning operations ceased on September 21. The average biochemical oxygen demand of the corn waste was 3,180 p.p.m. By December 9, the date of last observation, the biochemical oxygen demand was only 23 p.p.m. and the pH 8.4. The maximum distance at which any odor was noted was during the early part of the pea pack when a musty odor was detected at approximately 50 feet from the lagoon. To control odors with this degree of efficiency requires a thorough understanding and application of the treatment required. Treatment in newly constructed lagoons may give rise to some objectionable odor at times, owing to the absence of seeding organisms.

The untreated lagoon received pea and corn wastes under approximately the same conditions. On December 17, the biochemical oxygen demand of the waste in the lagoon was 2,000 p.p.m. and the pH 5.1. On April 11, the corresponding values were 358 p.p.m. and 7.3. Lagoon odors were obnoxious and caused numerous complaints.

It frequently happens that certain wastes are best handled separately from the general factory waste. For example, in canning plants, water used for cooling cans contains so little organic material that it may safely be discharged without treatment. Its value as a diluent of stronger liquid wastes does not justify the cost and operation of a larger treatment plant. The waste from preliminary washing of certain fruits and vegetables is also weak enough to permit direct discharge after screening.

On the other hand, certain wastes such as seepage from pea and corn ensilage stacks and spent lye solutions resulting from peeling operations carry so much pollutional strength that it is more economical to provide separate methods of disposal. Usually, the volumes of these concentrated wastes are low enough to permit hauling away in tank wagons. In some cases, the only trouble experienced with lye bath solutions is the intermittent discharge of a highly alkaline waste. In such cases the alkalinity may be neutralized with sulfuric acid or the waste may be impounded and discharged continuously at a very slow rate.

The lethal effect on fresh water fish of chemicals used in waste treatment and sodium hydroxide for lye peeling has been investigated. Concentrations of 50 p.p.m. sodium hydroxide, calcium hydroxide, or ferrous sulfate, 100 p.p.m. sodium carbonate or aluminum sulfate and 1,000 p.p.m. sodium nitrate in water of medium

hardness were not fatal and apparently not injurious to fish during a 7-day exposure. Concentrations twice as great were lethal to fish within 7 days.

It hardly seems necessary to emphasize that in designing any treatment plant, the capacity should be based upon the peak volume which may exist during the foreseeable future as a consequence of any expansion in operations. Time and again, disposal plants have been built to handle only the then existing volume of waste. Many such plants are now obsolete or require new construction which could have been incorporated more economically in the beginning.

The mechanics of disposal or utilization of trade wastes is largely the solution of the engineering problem of abating a public nuisance. In the food industry, however, waste disposal is also a matter of concern with respect to sanitation. To maintain a sanitary plant it is imperative that all waste material be promptly and completely removed from within the plant and from the adjacent area.

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USE OF THE DIRECT MICROSCOPIC COUNT AS A CONTROL MEASURE IN DAIRY PLANTS[1]

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The direct microscopic test on raw as well as pasteurized milk has been used in the Rockford milk control program for the past three years. Prior to this time the raw milk of each producer was tested every week with the reductase test and only plate counts were used on the pasteurized milk. Since it was rather apparent that with this type of program the maximum bacteriological improvement of the raw and pasteurized milk had been realized, it was thought worthwhile to investigate the possibilities of the microscopic count for this purpose. It had been noted for some time that bacterial counts on pasteurized milk were always higher with the advent of cold weather in January and February. This appears to be an unusual situation since cold weather should normally result in lowering the number of bacteria in raw milk and presumably also in the pasteurized milk. A frequent inference is that the raw milk must be at fault and thus the producers may often be incorrectly held responsible for thermoduric bacilli found in pasteurized milk. Allowing for the fact that some farmers get careless with the cleaning of their machines and expect the very cold weather to stop the growth of bacteria, our local experience indicates that the main source of these heat-loving bacilli at this time may be traced to favorable conditions for their growth on pasteurizing plant equipment. The most satisfactory explanation for this seems to lie in the fact that an excessive amount of moisture collects on the surface of vats, cooling coils, etc., at this season and permits the overnight growth of bacteria especially adapted to such an environment. Bacteria cannot live on perfectly dry surfaces, but will die sooner or later.

With suitable moisture conditions the rate at which bacteria can sometimes develop on milk plant equipment is astounding and unbelievable. Even though the milk is apparently all flushed off and the surface well cleaned, very small amounts of nutrient material may be sufficient to support extensive growth over night during a 15 to 18-hour period. After growth has taken place it is far more difficult to kill all the bacteria with a chlorine rinse in the morning than it is immediately after the cleaning-up period in the afternoon. If, at this time, a non-corrosive, penetrating type of sterilizing agent is sprayed or rinsed through the equipment the results are shown in lower bacterial counts on the following day. Although this double sterilization seems especially indicated in January and February, it would be of great benefit if used at all times. Since this appears at first glance to be unnecessary and just another extra job, it is not easy to persuade plant operators to do so unless they are having bacterial trouble.

Trying to locate the source of high bacterial counts in a pasteurizing plant with the plate count alone is a difficult matter. The bacteriologist or inspector who has only plate counts from milk samples taken at different steps in the heating process, merely has total numbers of bacteria to help him make a decision and this represents a circumstantial type of evidence. Unless he examines direct smears he has no way of knowing or seeing the types of bacteria actually causing any particular situation. Recognition of the types involved is of the greatest importance in tracing the source. If only the thermoduric bacilli are present the plant equipment is practically always

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involved. If many clumps of miscellaneous bacteria are found either the raw milk or plant equipment may be at fault. Large numbers of individual diplococci in the summer months are usually from the raw milk. When large numbers of cells and streptococci are present the mastitis angle needs attention. The type most frequently found in our work are thermoduric bacilli originating in the plant equipment. They are about as prolific, widespread and ubiquitous a nuisance to the milk plant operator as ragweed pollen is to a hay fever patient. A natural habitat of thermoduric bacilli, so called pin-points, appears to be in pasteurizing plants. They can be easily controlled if the plant operators will cooperate.

An extreme case of this type occurred in January 1943 and strongly brought to our attention the necessity for making direct microscopic counts routinely not only on the raw milk but also the pasteurized milk.

A certain dairy was having many complaints about the taste and odor of their pasteurized milk. Direct counts of the milk showed many millions of a relatively pure culture of thermoduric bacilli while the plate counts ranged from a few thousand to several hundred thousand pin points. Although this dairy was following the usual routine of cleaning and steaming equipment in the afternoon and passing through at least 100 ppm of chlorine in the morning, these organisms had succeeded in firmly establishing themselves. The raw milk from each producer was checked with direct counts on several occasions at this time and found to be very good. The log averages of the direct counts on the raw milk were from 30,000 to 40,000 per ml. and the direct counts on the pasteurized milk ranged from three to thirty million per ml. and on a few occasions reached 100,000,000 per ml. When a strong solution of a surface active sterilizing agent was passed through the equipment immediately after cleaning in the afternoon, the direct count of the pasteurized milk on the following day dropped from 100 per field to less than one in thirty fields, or from thirty million to less than 10,000 per ml. By no stretch of the imagination could the raw milk be involved in this situation, and growth of the organisms in the equipment during the heating process was also an unimportant factor. Many similar but less extreme cases have since been noted. To a minor and not so noticeable an extent the same condition involving the growth of thermoduric bacilli on equipment, is constantly being repeated in many plants using similar operating technique. If direct counts were made on the milk the condition would be quickly revealed and as easily eliminated. The relatively new surface active, penetrating and non-corrosive sterilizing agents have a definite place in preventing bacterial growth from developing on equipment surfaces. A strong protective film of this material will kill practically all residual bacteria and prevent any subsequent growth from developing over night.

It has been our experience that the direct count can be used on both raw and pasteurized milk to improve the operating technique on the farm as well as the plant. When the raw milk has a high count in excess of 200,000 per ml. the information obtained is sent to the producer with suggestions as to the cause of the trouble and advising him that it will have to be taken care of if he wishes to continue sending in his milk. A high count on pasteurized milk is not so easy to interpret and may require direct counts on producers also. In general, such high counts may be due to either high count raw milk or holdover pasteurized milk containing thermoduric organisms, or insufficient cleaning and sterilization of plant equipment, including practices which may result in the growth of thermoduric types on the equipment. It has also been our experience that plants, in which the equipment is efficiently cleaned and sterilized, have monthly log averages of direct counts on the pasteurized milk which are usually less than the log averages of their raw milk. If the log averages

of the direct counts of the pasteurized milk are much in excess of the raw milk, it is usually caused by faulty operating methods.

Because of the relatively greater numbers of heat-resistant bacteria in raw milk with a very high count, the pasteurized milk in such cases may have correspondingly high direct counts, although they are not always reflected in the plate counts.

The question of the significance or interpretations to be placed upon the dead bacteria which may also be counted in the direct method, has appeared to be a deterrent to the use of this method on pasteurized milk. If we are using the direct count for plant control purposes what difference does it make whether a few of them may be dead? Our main purpose in using the test on pasteurized milk is to place a bacterial ceiling, dead and alive, on the heated milk that corresponds to the ceiling on the raw milk. If the raw milk ceiling or standard is 200,000 per ml. why should the ceiling on the pasteurized milk be permitted to greatly exceed this amount whether the bacteria are alive or dead? A good quality of raw milk that is processed in a clean, well operated plant will always result in pasteurized milk with a direct count under 200,000 per ml. unless many bacteria are added from the plant itself. It should always be remembered that no high quality milk or cream contains an excessive number of bacteria whether they are alive or dead.

One of the greatest advantages of the direct count in examining pasteurized milk is the small amount of time required. A count can be obtained on the sample on the same day collected and this permits a close study of the plant operating methods to be made on the day the milk is processed. It is more difficult to correlate such methods with counts that are two days old. In one instance where a pasteurized milk sample was found to have millions of thermoduric bacilli, an inspection made on the same day the sample was collected showed that the operator was holding over a few cans of pasteurized milk to be used for standardizing purposes on the following day. The milk in the cans likewise had extremely large numbers of similar bacilli. The situation was explained to the operator and the following day the pasteurized milk had a very low normal count. A correction requiring only a few hours, was made in this case, two days before the difficulty itself would have been known, if a plate count only had been made. To correct the matter by using plate counts would have required several additional days and a great deal of laboratory work. The plate count appears to be a leisurely and expensive procedure by which information is obtained that seems to have more of a mathematical than a true bacteriological significance insofar as control work is concerned.

The mere estimation of numbers of bacteria is hardly comparable in informational value to the combined estimation and recognition of the types involved. The idea of obtaining bacterial counts in a matter of minutes instead of days may represent a difficult adjustment from previous routine methods, but its value can only be determined by an adequate trial. Progress in the bacteriological control of milk supplies will take place only to the extent that better bacteriological techniques are applied to routine control methods.

The laboratory pasteurization of individual raw milk samples to detect thermoduric or heat-resistant bacteria is a practice that has been used more or less extensively in some milk control laboratories. Our experience has been that this is unnecessary when direct counts are made routinely on all producers. If the producers having counts over 200,000 per ml. are rechecked and required to correct the situation, the raw milk will have so few thermoduric types that the laboratory pasteurization of individual samples becomes unnecessary. The direct counts give immediate information and represent far less laboratory work as well as less equip-

ment and material. The farmer who uses such careless technique that his milk has a bacterial range from 200,000 to 1,000,000 or more, may produce milk that pasteurizes to a low figure on some days and very high counts on others. Regardless of whether the bacteria in such milk are heat-resistant or some other type, the milk has not been produced in a satisfactory manner.

In order to use the direct microscopic test on pasteurized milk there does not appear to be any reason that the results obtained through its use should correspond or parallel the results obtained with the plate count on the same sample. They cannot be expected to be closely comparable since the techniques and factors involved are quite different. Actually, these differences, instead of being objectionable, in our experience are helpful and of considerable practical value. The plate count estimates only the bacteria that are capable of growth under certain conditions of temperature, nutrient material, length of incubation, etc. In this respect the bacteria present in milk vary greatly in their requirements. The direct microscopic count gives an estimate of all the stainable bacteria present, regardless of their growth requirements or their physical condition after the heating process. If the count is made for the primary purpose of maintaining a bacterial ceiling corresponding to that of the raw milk the significance is quite different from that of the plate count. Bacterial plate counts are made on pasteurized milk to determine whether the number of living organisms present and capable of growth, is less than an arbitrary official standard. The direct microscopic counts can be made on pasteurized milk to reveal whether the total number of all bacteria, dead or alive, irrespective of growth, is less than the standard applied to the raw milk. If they do greatly exceed this standard it is at once obvious that either bacteria are being introduced from the plant equipment or the raw milk is not of satisfactory quality.

In either case the cause can be quickly determined and the unsatisfactory situation corrected in a short time and not after a lapse of 48 hours. The fact that the unofficial direct microscopic standard of the pasteurized milk is the same as for the raw milk makes the direct count particularly suitable for plant control purposes. Although it may seem paradoxical, a microscopic standard of not over 200,000 per ml., in our experience, is more severe than a plate count standard of not exceeding 30,000 per ml. The natural assumption would be, of course, that the higher the ceiling permitted the poorer the bacterial quality of the milk. The reasons for this situation are not easily explained but are intimately related to the heating process that is given the milk and the resultant effect on the bacteria present.

It may not seem logical, but our experience in trying to enforce a direct microscopic standard of not over 200,000 per ml. on pasteurized milk has resulted in a sharp decline of plate counts far below the 30,000 level. Much of the decline has been due to the focussing of attention to the methods used in the pasteurizing plants, but a considerable share of credit is due to the improved quality of the raw milk brought about by the microscopic test also.

A brief outline of our present program is given as follows:

RAW MILK

1. ANNUALLY: *For "An Over-all Farm Picture"*—One or more annual routine farm inspections for control of structural, equipment and operational items.
2. MONTHLY: *To Check Producers "Performance Ability"*—Direct microscopic laboratory examinations of the milk from each producer.
   a. Notices and letters with explanatory information sent to producers having counts over 200,000 per ml. with rejection following if recheck samples are not satisfactory.
   b. Special farm inspections for educational purposes usually, but not always made before rejection takes place. The past performance record of all producers is on file and habitual offenders are shown the record and advised to find another market.

3. SPECIAL: *To Assure "Physiologically Pure Milk"*—Herds with extensive mastitis infection are detected by the presence of excessive leucocytes as shown by the routine direct microscopic tests.
   a. The owners of such herds are advised to (1) have a veterinarian make a physical examination of each animal, (2) eliminate all animals found unfit, (3) develop and maintain *Streptococcus agalactiae* free herds.
4. SEMI-MONTHLY: *To Note Milk Cleanliness*—Sediment platform tests with bottom can samples.
   a. Rejection of milk having poor tests.
5. DAILY: *Platform Checks*—To note off odors, high temperature and abnormal appearing milk.
6. MONTHLY: *Record of Performance*—Tabulation of direct microscopic counts from individual producers by loads. Logarithmic averages recorded by months and by dairies.

PASTEURIZED MILK

7. BI-WEEKLY: *To Obtain "An Over-all Plant Picture"*—Inspections of pasteurizing plants for operational and structural items.
8. SEMI-MONTHLY: *To Note "Operators' Performance Ability"*—Collection and examination of pasteurized milk with (1) direct microscopic count, (2) plate count, (3) coli count, (4) phosphatase and (5) butter fat tests.
   a. Follow-up inspections to find cause of excessive direct microscopic counts over 200,000 per ml.
   b. Swab tests of plant equipment whenever necessary for educational and bacteriological control purposes.
9. MONTHLY: *Record of Performance*—Recapitulation of bacteriological tests.
   a. Logarithmic averages of direct microscopic counts and plate counts recorded by months and by dairies.
   b. Range of direct microscopic and plate counts recorded by months.

In order to obtain a good quality of pasteurized milk it is, of course, of the greatest importance to start with a good quality of raw milk of low bacteria count. There are individual exceptions but as a general rule the higher the bacteria count from a producer's milk sample the greater will be the number of thermophilic and thermoduric bacteria present in the milk. The percentage of such types in any farmer's milk is not constant, but will vary from one day to another. For this reason it is important that a standard of not over 200,000 per ml. should be enforced and maintained for all the producers and not a selected few. Our experience has been that this standard is fair and equitable and not too difficult for a herd owner to meet. A monthly microscopic test appears to be often enough except during the warm summer months. The increased temperature makes it necessary to use greater care in cleaning and sterilizing utensils as well as attention to proper cooling. Mechanical refrigeration is highly desirable.

A comparison of the reductase and direct microscopic tests made over a three-year period indicated that the latter test was more sensitive and selected three times as many producers with unsatisfactory milk as did the reductase test. It is of considerable interest that the greater selectivity was largely concentrated in the range from 200,000 to 1,000,000 per ml. In this area the microscopic test detected seven times as many as the reductase test. Among the samples over one million the microscopic test detected half again as many as the reductase test. Two percent of the tests were in disagreement with a microscopic test under 200,000 per ml. and a reductase test of six hours or less.

When the microscopic test was compared with the plate count in a rather small series of tests, the log averages of the plate counts on samples having large numbers of bacteria were considerably higher than the log averages of the microscopic counts.

Raw milk producers that are consistently careful in their methods can maintain low counts the year round. About 10 percent are habitually careless, indifferent, and

always in trouble. The best policy seems to be to weed these individuals out of the Grade A market, since they will never learn to produce quality milk. They can cause more trouble and inspection work than all the rest combined. A big majority of the farmers are willing to cooperate and will voluntarily reduce high bacterial counts on their milk when the matter is brought to their attention with a notice or letter. Dairymen with herds having a high percentage of advanced infectious mastitis find it difficult to meet bacterial standards in the warmer months and have to eliminate some animals and treat others. Since this disease represents a serious economic problem, they are usually very glad to initiate control methods and use good herd management.

When direct microscopic tests are made on individual producers of milk, the information obtained is recorded under four divisions: (1) direct microscopic estimate, (2) utensil contamination, (3) poor cooling, and (4) udder infection. If the estimate is over 200,000 per ml. a card is sent to the producer indicating the probable cause of the trouble and suggesting that it should be corrected. A few days later a recheck is made, and if this is still unsatisfactory a letter is sent and a second recheck made.

For the past three years about 80 percent of the raw milk samples and also the pasteurized milk samples have been below 200,000 per ml. with direct microscopic counts. Improvement in the pasteurized milk is reflected in a decrease in plate counts over 30,000 per ml., from 31 percent in 1942 to 11.2 percent in 1945, and an increase in counts of 1,000 or less, from 4.0 percent in 1942 to 28.3 percent in 1945. The improvement is also shown in the log averages which were 8,000 in 1943 and 4,000 in 1945.

It is interesting that the highest plate counts on pasteurized milk have been obtained during January and February, even though the raw milk is of normal good quality. This is believed to be due to favorable conditions existing in the pasteurizing plants for the growth of bacteria during this period. The high direct microscopic counts obtained during July, August, and September are unquestionably from the raw milk, but are not reflected in the plate counts.

At the time the local program was started in January, 1943 it was found that all of the plants except one had much higher microscopic counts than appeared to be either necessary or desirable. From two to three months of intensive control work, such as plant checks, swab tests, and educational work, was required to reduce the bacterial counts, both plate and microscopic, to fairly low levels. Prior to the time the program was started, it was realized that the plate counts as a whole were none too satisfactory, but it required the very high direct microscopic tests of the pasteurized milk to bring about a full and complete realization to all parties concerned, that the situation was unnecessary and capable of correction. The microscopic test in effect provided the extra added incentive necessary to action. A direct microscopic ceiling of 200,000 per ml. seems to provide a more practical and forceful leverage than is possible with a plate count ceiling of 30,000 per ml.

A close comparison of the effect of operating methods upon bacterial counts obtained from various pasteurizing plants is not easily possible with plate counts alone. This can be done more effectively when microscopic counts of the raw and pasteurized milk are also available for comparison. Our experience indicates that when the log averages of the microscopic counts of the raw milk ranges from 30,000 to 50,000 per ml., and at least 80 percent of the producers have counts under 200,000 per ml., then it may be a reasonable expectation that the monthly log average plate counts of the pasteurized milk will vary from 1,000 to 5,000 per ml., depending upon individual differences in operating methods. It is interesting in

this connection that 82 percent of all the plate counts from 0 to 1,000 per ml. were from four of the eight plants.

In making microscopic counts on raw milk thirty fields are counted unless there are one or more bacteria in ten fields, and in these cases ten fields are counted. On pasteurized milk thirty fields are counted and if one or no bacteria are found a minimum count of 10,000 is recorded. On both raw and pasteurized milk clumps of bacteria are counted. Both the methylene blue and Broadhurst stains have been used for staining. During the past year a new stain has been used. This has given higher counts than the other two and also reduces eyestrain. An orange Wratten M. filter E No. 22 is used in front of the light source. The bacteria have a purplish black color and contrast sharply with the background.

In using the Mallmann stain, 0.5 ml. of concentrated hydrochloric acid is added to 500 ml. of 95% ethyl alcohol containing 1% methylene blue.

Referring to the coliform test which is used for detecting recontamination of milk after pasteurization, it has been our experience that the test is only in part related to equipment cleanliness. It frequently fails to give an indication when the equipment has not been cleaned and sterilized properly. On the other hand, it frequently gives positive tests over one per ml. on samples having only a few hundred colonies with the plate count. While it may seem desirable to have a standard of not over 1 per ml., it does not appear practical to insist on a more severe standard than 10 per ml. If the coliform test is used in conjunction with the direct microscopic count of pasteurized milk, a better and more effective control is obtained over the plant operating methods than if used alone.

A small number of cream samples were examined and the results indicated an improvement similar to that of the pasteurized milk.

In order to obtain information relative to the bacterial quality of pasteurized milk from pasteurizing plants not subject to routine direct microscopic control, 21 samples from 15 dairies were tested. The direct counts ranged from 10,000 to 18,000,000 per ml. Five were over one million and 57 percent were in excess of 200,000 per ml. With the plate count 43 percent were in excess of 30,000 per ml.

SUMMARY

1. The direct microscopic count when applied to pasteurized milk has been found to be of considerable value in tracing the effect of seasonal influences upon the bacterial quality.

2. With the information obtained by this method it has also been found possible to quickly rectify faulty plant practices that cause the introduction of thermoduric organisms in relatively small or large numbers.

3. The microscopic count has special significance as a plant control measure, either alone or used in conjunction with the coliform count.

4. A review is given of results obtained in a municipal milk control program through the application of the direct microscopic test to raw and pasteurized milk over a three year period.

CONCLUSIONS

1. The direct microscopic test, if used intelligently, has many advantages in bringing about improvement in the bacterial quality of raw and pasteurized milk.

2. The statistical results obtained during three years of routine experience with this test indicate that a significant improvement has taken place.

SIGNIFICANCE OF BACTERIAL GROWTH CURVES IN FOOD PLANT CONTROL[1]

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Food packing has through years of progressive development grown in scope and complexity until now it consists of a multitude of varied and technical processing operations. The processing operations to which any given food is subjected in the present-day food plant are so interrelated with respect to their influence on quality of the finished product that the control necessary during any one operation is dependent both on how the food was handled in previous operations and on the control possible in subsequent operations.

The large present-day food plants are departmentalized to the extent that a food product may receive handling by a number of departments during its course of preparation. Under such a system standardization of operations is essential to the production of food items of uniformly high quality. For example, the thermal process required to sterilize a canned food item depends greatly upon how the food is handled during preparation. If a process is employed which is sufficiently severe to sterilize a food regardless of how it has been handled in previous operations the quality of the finished product will seldom be either high or uniform. The rate of thawing of a food which has been stored in the frozen state will necessarily depend to some extent on how the food was handled prior to its being frozen. The temperature of refrigerated storage and the length of time a food may be safely stored at a given temperature are determined to a great extent by how the food is handled prior to storage. These are only a few of the examples which might be cited to emphasize the interrelationship of processing operations; but, they will serve to illustrate the necessity for standardization of operations if uniformly high quality food products are to be manufactured.

Education as the result of advances in the science of nutrition and in general food technology has placed present-day emphasis on quality. As the education continues greater emphasis still will be placed on quality. Competition with respect to both organoleptic and nutritive qualities of processed food will in the future be so keen that the food packer will need to use every facility at his command to manufacture uniformly high quality food products.

How can the bacteriologist best serve the food packer in his efforts toward the production of higher quality food products? First, by applying available information concerning principles which govern bacterial growth behavior in foods, the bacteriologist can materially aid in standardization of practically every food processing operation. Second, by well designed research he can obtain valuable information upon which to base improvements in present-day methods of processing.

Food packing may well be considered as representing a battle between man and microbe. Therefore, application of knowledge concerning the growth behavior of bacteria should constitute the initial step in the packer's effort to "outwit" the microbe. Bacterial decomposition of food or food components is brought about by the growth of bacteria in the food. An understanding of the factors which influence bacterial growth is for this reason essential to successful food plant control.

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 19, 1946.

THE BACTERIAL GROWTH CURVE

Under any given set of conditions, growth of bacteria can be represented by a curve which assumes rather a unique form. Such a curve, representing increase in number of bacteria with respect to time, is known as a growth curve. Excellent discussions of various factors which influence bacterial growth and therefore the nature of bacterial growth curves have been given by Hammer *(1)*, Jensen *(2)*. Tanner *(3)*, and Zinsser and Bayne-Jones *(4)*. The basic principles governing growth behavior of bacteria, brought out in these treatments of the subject, have served as the background for the discussion which follows.

For the purpose of this discussion, a curve (Fig. 1) has been constructed by plotting the logarithms of assumed numbers of bacteria, per unit volume of food, in the direction of ordinates against time in the direction of abscissae. The curve shown in Fig. 1 is hypothetical; however, it is hypothetical only in the sense that it does not represent actual data. It does represent in a general way the growth behavior of bacteria subsequent to their being transferred from an unfavorable environment to one which is favorable for their growth.

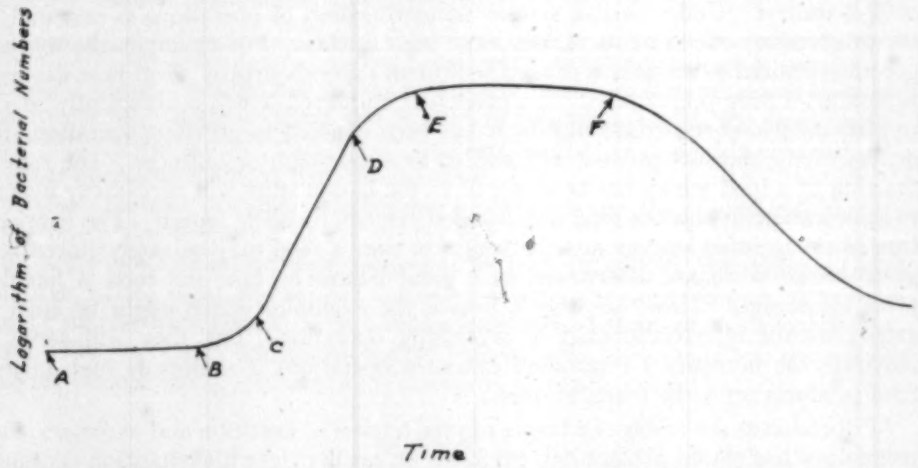

FIG. 1. The bacterial growth curve represents, in general, the growth behavior of bacteria.

Bacteria when subjected to certain adverse conditions will become virtually inactive with respect to growth. When such organisms are again subjected to favorable conditions for growth, it is only after an appreciable lapse of time that growth occurs in the form of cell reproduction. This period of growth lag is referred to as the lag phase (A to B, Fig. 1). At the end of the lag phase, bacteria start multiplying; and, very soon thereafter, increase in number of bacterial cells is directly related to time. This is the phase of rapid growth and is represented by a straight line (C to D, Fig. 1).

The number of bacteria in any medium, probably because of the exhaustion of nutrients essential for growth and because of the accumulation in the medium of metabolic products inimical to growth will eventually reach a maximum and the number present will remain virtually constant at this maximum for a period of time. This period, represented by the flat portion of the growth curve (E to F, Fig. 1) is known as the stationary growth phase. After a certain length of time death of the cells begins. The resulting period of decline and death is represented by the receding portion of the curve. From the standpoint of food plant control

chief interest lies in factors influencing the length of the lag phase and the rate of growth of bacteria in the rapid growth phase. Therefore, only the lag phase and the rapid growth phase will be discussed further here.

It should be emphasized that a curve representing the growth behavior of a given species of bacteria under one set of environmental conditions will never be identical in form to a curve representing the behavior of the same species under any other set of conditions. For example, with changing conditions, the length of the lag phase may vary from less than an hour to many hours or even days. Furthermore, the rate at which bacteria will multiply in the phase of rapid growth, will depend upon many different factors. The factors commonly considered as exerting the greatest influence on the character of these growth phases are:

(1) Number of bacteria in product initially, (2) age of bacteria present, (3) frequency with which bacteria are transferred to new media, (4) growth phase of bacteria at the time they are transferred to new media, (5) kind of bacteria present in product, (6) temperature of bacterial environment, and (7) nature of substrate supporting bacterial growth.

DISCUSSION OF FACTORS

The significance of these factors with reference to bacterial development in foods will now be considered. Such considerations will be based on the proposition that the ideal of food plant operation, toward which the food packer should be persistently working, is to accomplish all processing steps during the lag phase of microbial growth.

Number of Bacteria. Generally speaking, the greater the number of organisms present, the shorter will be the lag phase of growth and the more rapidly will bacterial multiplication occur in the rapid growth phase. Hence, every practical effort should be made to hold to a minimum the number of organisms finding their way into a product. To do this involves a rigid program of food plant sanitation, in which disinfection plays a major role. By way of example, if food handling equipment is not properly cleaned, bacteria may grow in the small amounts of food remaining on it and heavily contaminate food subsequently handled by the equipment. Extensive research in the dairy, meat and other food industries has established that improperly cleaned food handling equipment constitutes one of the most potent sources of contamination. Contaminated water supplies, contaminated ice, and poor quality minor product ingredients are often important sources of contamination. Eliminating the major sources of contamination, which may be located by flow sheet methods of bacteriological analysis, is the first step toward making it possible to carry out all processing operations within the lag phase of bacterial growth.

Age of Bacteria. The older organisms become the longer their lag phase of growth will be. It is obviously impossible to determine the exact age of organisms present in a food product. However, knowing the sources of contamination will often allow for fairly accurate conjecture as to the behavior of bacteria in a food product. For example, consider a number of organisms entering food with dust contamination in comparison with the same number entering with small amounts of food which have remained for several hours on improperly cleaned equipment. Organisms entering with the dust will ordinarily be relatively old and will show considerable growth lag. Organisms in the food left on the equipment will, on the other hand, very likely be quite young and after entering the fresh food may demonstrate very little or no growth lag. Hence, it is far more important to keep idle equipment free of small amounts of food than it is to keep it dust free.

Frequency of Transfer and Growth Phase of Bacteria Transferred. Frequent transfer of organisms to new media will tend to keep them in the phase of rapid growth. If bacteria are in the lag phase of growth when transferred to fresh product, they will begin rapid growth only after completion of their lag phase. If the bacteria are in the rapid growth phase when transferred, they will probably continue to grow in the fresh product at a rapid rate. Bacteria in small amounts of food remaining on improperly cleaned equipment are frequently in the rapid growth phase when fresh food is again handled by the equipment and when entering the fresh food, instead of showing a lag in growth, these bacteria often continue to grow at a rapid rate. If the temperature of food, handled by equipment located in a warm room, never exceeds 40° F. it might be thought that any bacteria entering such food would immediately stop growing. However, this is seldom the case if the bacteria entering the food are in the rapid growth phase. Bacteria will continue rapid growth at temperatures far below the minimum temperature which will initiate their rapid growth. Hence, all food handling equipment located where the temperature is currently above 50° F. should receive special attention in cleaning procedures. If the temperature of the food is favorable for bacterial growth, it is often desirable to clean certain food handling equipment periodically during the day in order to prevent bacteria, in food adhering to the equipment surfaces, from reaching the phase of rapid growth. Equipment having wood, or other porous, or rough surfaces which contact the food must receive careful attention in order to prevent it from becoming a hazardous source of bacteria in the rapid growth phase. Recesses, in food handling equipment, in which food may accumulate and be overlooked in routine cleaning procedures should be eliminated insofar as possible.

Kind of Bacteria. Knowledge concerning the types of bacteria which may be present is often extremely valuable. Different species of bacteria vary considerably in their growth behavior when subjected to any given set of environmental conditions. Bacteria will show the shortest lag in growth under conditions most favorable for their growth. A knowledge of the kind of bacteria present will often allow for adjusting conditions so that an essential operation may be completed before appreciable growth occurs in the product. For example, if it is known that thermophilic bacteria are present in a product to be canned and heat processed, and that these bacteria will not be killed by the thermal process to be given the product, it is generally possible to cool the product, subsequent to thermal processing, rapidly enough to avoid initiating active growth of the bacteria surviving the process. In fact, this is a common practice for handling certain foods known to be contaminated with thermophilic bacteria. It is a classical example of operating within the lag phase of bacterial growth. The kinds of bacteria present will depend primarily upon the sources of contamination; and, a study of the sources of contamination will often lead to the possible elimination of bacteria which make certain operations difficult.

Temperature. Temperature control provides one of the greatest weapons against active bacterial growth. The length of the lag phase and the rate at which bacteria multiply in the rapid growth phase are influenced markedly by the food temperature. By temperature adjustment alone it is often possible to lengthen the lag phase of bacterial growth sufficiently to permit a processing operation to be completed before active bacterial growth occurs in the product. The lag phase of growth of bacteria in many perishable foods may be lengthened by as much as 100 percent by maintaining the temperature of such foods at 50° F. instead of 65° F. during certain processing operations; and, by lowering the temperature of food holding coolers

from 50° F. to 40° F. it is often possible to lengthen the lag phase, of surface contaminats of foods stored in the coolers, as much as 200 percent.

Adequate temperature control during food cooling operations is essential to the prevention of spoilage unless the food is sterilized prior to cooling. Cooling nonsterile foods in bulk is a common industry practice; for example, cooling of pasteurized milk, of meat immediately subsequent to animal slaughter, of foods to be preserved in the frozen state, of many canned food items subsequent to thermal processing, and of many different foods during various processing steps. The rate of cooling should be such that the temperature of the product is lowered rapidly enough to prevent any appreciable increase in the number of bacteria present. If favorable bacterial growth temperatures prevail sufficiently long to initiate rapid bacterial growth significant spoilage may occur before this rapid growth can be stopped. Lower temperatures are required to stop growth of bacteria in the rapid growth phase than are required to keep bacteria in an inactive state of growth. This can best be illustrated by superimposing food cooling curves on the growth curve shown in Fig. 1.

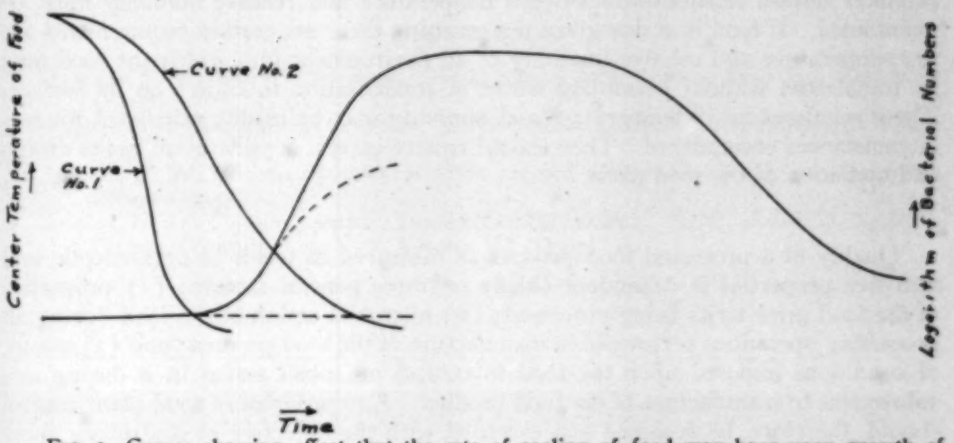

FIG. 2. Curves showing effect that the rate of cooling of food may have upon growth of bacteria in food.

Fig. 2 graphically illustrates what may be expected upon cooling a food product at each of two different rates. It will be noted that cooling curve No. 1 intersects the growth curve near the end of the section of the curve representing the lag phase of bacterial growth. The broken line projected from the point of intersection of the two curves represents subsequent bacterial growth to be expected. Cooling curve No. 2, on the other hand, intersects the portion of the growth curve representing the rapid growth phase. The broken line projected from this point of intersection again represents subsequent bacterial growth to be expected. These effects have been observed many times in commercial practice and it has been found that sufficient study of the growth behavior of bacteria commonly present in a given food product will dictate, within very close limits, the rapidity with which the product should be cooled.

Nature of Medium. Composition of the substrate medium will influence markedly the length of the lag phase of bacterial growth and the rate of growth of bacteria in the rapid growth phase. Water content, pH of food, salt content and many other factors are important in this respect. Certain salts have long been used as inhibitors of bacterial growth. Various organic acids have been widely used as preservatives.

The effectiveness of these inhibitors increases directly with increases in their concentrations in food products.

From the standpoint of food plant control water contents should receive special consideration. Other things being equal, the more free water present in, and on the surface of, a food product the shorter will be the lag phase of bacterial growth and the greater will be the growth of bacteria in the rapid growth phase. Free water influences bacterial growth to a far greater extent than does bound water—free water being defined as that which is present in excess of that bound physically and chemically with other substances in the food. There is some free water naturally present in most fresh foods; but, with reference to food plant control, the concern is not primarily with the naturally occurring free water but with water added in washing procedures, with water which may collect on the surface of foods during handling operations, and with water added as an ingredient of a food product. The lower the free water content is kept the greater will be the possibilities for bacteriological control.

To prevent free water from collecting by condensation on the surface of food products certain relationships between temperature and relative humidity must be maintained. If food is at one given temperature, there are certain requirements for the temperature and relative humidity of an environment into which the food may be transferred without permitting water of condensation to collect on its surface. These relationships of temperature and humidity may be readily calculated for any circumstances encountered. They should receive careful consideration in the design and operation of the food plant.

PRACTICAL CONSIDERATIONS

Quality of a processed food product as measured in terms of organoleptic and nutritive properties is dependent chiefly on three general factors: (1) properties of the food prior to its being processed; (2) microbial action in the food during all processing operations performed in manufacture of the food product; and (3) nature of conditions imposed upon the food to control microbial action in it during and subsequent to manufacture of the food product. Any program of food plant control should, therefore, be designed and executed with the objective of controlling these three general factors. The following suggestions for a program of food plant control, based on the foregoing discussions, are offered in the hope that they may prove helpful to the food packer in his future efforts toward product quality improvement:

1. Set as the objective, the execution of all processing operations within the lag phase of microbial growth.
2. Institute routine bacteriological flow sheet analysis to cover every processing operation during manufacture of every food product.
3. Establish bacteriological standards for foods and product ingredients used in the manufacture of each food product.
4. Eliminate all major sources of contamination as located by flow sheet analyses.
5. Correct conditions which flow sheet analyses have established as allowing significant increases in bacterial numbers during any processing operation.
6. Temperature of food during such operations and time food is held at such temperatures should be adjusted according to requirements established by growth curves, of bacteria in food, obtained under controlled conditions of food incubation.
7. Eliminate addition of free water to food wherever possible—especially water collecting on product through condensation. The latter may be eliminated by proper adjustment of temperature and humidity relationships.
8. If it is found that the entire lag phase is being consumed in a number of processing operations and leaving no operating time for succeeding operations, apply the same principles for adjusting conditions of all operations as were applied for adjusting those of a single operation. Strive to adjust conditions so that all operations may collectively be accomplished during the lag phase of bacterial growth.

9. If the thermal process used for sterilization or partial sterilization is more severe than that considered necessary for safety from the standpoint of consumer health, determine by routine analyses the process necessary to accomplish the desired degree of sterilization and adjust the time and temperature of thermal processing accordingly.

OBJECTIVE CONSIDERATIONS

There is an urgent need for well-planned research designed to establish formulae by which the growth behavior of bacteria in foods can be predicted. The program of food plant control outlined above if executed simultaneously with such research should provide ample bases for mathematical formulae by which the practical limits of many operating conditions such as temperature, relative humidity, degree of sanitation, and time of operation could be accurately estimated for processing any given food product in any given food plant. Quality improvement will depend chiefly upon scientific food plant design and control. The application in the food plant of information to be gained from a study of growth behavior of bacteria, as depicted by growth curves, will materially aid in accomplishing product improvement through scientific control.

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BACTERIOLOGICAL ASPECTS OF FOOD HANDLING AND PROCESSING[1]

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Food microbiologists are concerned primarily with (1) the spoilage of foods by bacteria, yeasts, or molds; (2) the microbiological control of procedures involved in food processing; and (3) the safeguarding of foods from pathogenic microorganisms.

Wartime mobilization and the deployment of troops to all regions of the world provided an excellent opportunity for evaluation of methods of processing and storage of food. Introduction of new methods of food processing and the necessity of preparing foods for use and storage under varied climatic conditions confronted the food industry with new problems and accentuated existing ones. The war, further, provided the impetus for a concerted attack on these problems. Certain "commercially sterile" canned goods, for example, may contain thermophilic bacteria which at usual temperatures do not develop, but which may at the storage temperatures of the tropics *(1)*.

The great loss of ships during the early stages of the war put a premium on shipping facilities which necessitated changes in processing methods to give a product that required a minimum of shipping space. Consequently great effort was expended by both government and industry in the development of dehydrated foods. From a bacteriological point of view, it was necessary to control bacterial spoilage and to make sure that the product was safe from the standpoint of food poisoning and food-borne diseases. Dehydrated meat *(2)* was found to be safe when produced in accordance with the process recommended in the federal specifications. Deboned meat was ground and given a precooking treatment for a minimum of thirty minutes at not less than 165° F. internal temperature. This temperature is higher than that of the pasteurization of milk (143° F. for 30 minutes), which has been shown to kill staphylococci, *Brucella* and other non-spore forming pathogenic bacteria. *Trichinella spiralis* would also be destroyed since a temperature of only 137° F. is required to kill this parasite. After precooking, the product was dried rapidly so that no particle within the packaged container had more than ten percent moisture. Molds and bacteria do not multiply at this moisture content. Streptococci, staphylococci and *Clostridium botulinum* spores experimentally inoculated into dehydrated meat failed to develop when the moisture content was thirty percent or less. Salmonella organisms similarly inoculated into dehydrated meat did not grow until the moisture content was above fifty percent. The Federal specification of ten percent moisture, therefore, is well within the safety limits from the microbiological point of view.

Dehydrated eggs or egg powders presented a problem which was different from that of meats. It is not possible to precook the eggs during processing without ruining the product.[2] Therefore, pathogenic microorganisms, which may be introduced from various sources and may withstand the dehydration and storage, will constitute a danger if the egg powder is used without cooking.

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[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 18, 1946.

[2] NOTE: Since this paper was prepared a report has appeared on the pasteurization of liquid egg products (Winter and Stewart, McFarlane and Solowey) in the American Journal of Public Health, 1946, *36*, 451-460.

Reports of the isolation of Salmonella organisms from samples of dried egg powders supply evidence of the possible role of these foods in transmission of this infection. Gibbons and Moore *(3)* isolated Salmonella from 28 of 380 samples of Canadian dried egg powder. They reported nine species of *Salmonella*, namely: *S. bareilly, S. pullorum, S. oranienburg, S. typhi-murium, S. thompson, S. minnesota, S. newport, S. manhattan,* and *S. potsdam.* Of 21 samples in which Salmonella counts were made, 13 contained less than one organism per gram, 7 between one and ten per gram, and 1 fifty-four per gram. Positive cultures were obtained from first grade powders during warm months. Similar reports have been made in this country. *Salmonella tennessee* was isolated by Schneider *(4)* from powdered eggs and from frozen whole eggs obtained in Iowa. *S. tennessee* and *S. oranienburg* were isolated from egg powder received from Nebraska.

The source of the Salmonella in eggs may be from the hen *(3, 5)*. Since this means that not only eggs but also the meat of infected fowl may be infectious, it is important that more study be given to Salmonella infections in chickens. The current policy of defining the Salmonella group on the basis of the antigenic characteristics of the organisms has changed our concepts of this group of bacteria. An evaluation of the pathogenicity of new species for man and a correlation or simplification of classification consistent with their pathogenicity is urgently needed.

The problem of food-borne salmonellosis is of course not confined to the poultry industry but is a well recognized problem in industries engaged in food processing and handling.

Brucellosis, like salmonellosis, is a disease of animals which unfortunately is transmissible to man. Brucella organisms are present in the tissues of infected goats, hogs and cattle and in infected goats' and cows' milk. Individuals handling tissues or drinking raw milk from infected animals may develop the disease. Since the tissues of infected animals may have no gross pathology, post-mortem examinations by competent Federal meat inspectors will not reveal brucellosis. Attempts to control the disease by slaughtering infected animals and by immunization have met with only limited success. Recent investigations have not clarified the epidemiology of brucellosis. For example, suis strains have been responsible for milk borne outbreaks *(6, 7, 8)*, and caprine strains have been associated with persons working with hogs *(9)*. The extent of the infection in consumers or handlers of infected food is not known and is in need of further investigation.

Of the food-borne infections caused by higher parasites, that of trichinosis is among the most frequent. In 16.2 percent of 11,931 necropsies on man, trichinae were found *(10)*. Obviously trichinosis was not the cause of death in these cases coming to necropsy and no histories suggestive of trichinosis were generally available. Trichinosis is caused from eating improperly cooked fresh pork infected with *Trichinella spiralis.* Pork in "ready to eat" products is preheated or frozen according to Federal meat inspection regulations and is not a source of danger. At the present time there is no simple method for recognizing this infection in swine at the time of slaughter, and recommendations to cook thoroughly all garbage fed to hogs and to eat only well cooked pork are too often ignored. In spite of these warnings, trichinosis is still a problem. There is need for a simple means of detecting this infection in food animals before the disease may be adequately controlled.

The food microbiologist has been struggling for years with the problem of staphylococcus food poisoning. Sizeable outbreaks of staphylococcus food poisoning have been reported during the war. In one camp a single outbreak *(11)* involved about 4,000 men who had eaten bread pudding which had been stored beneath a

steam table for sixteen hours. In six outbreaks reported in the Navy *(12)* during 1942, 3,384 people were involved. All of these six outbreaks were due to ham, and in one of them 2,128 persons were made ill. Lack of adequate refrigeration and poor handling were responsible for most of the outbreaks.

A wide variety of foods, such as meat and meat products, dairy products, bakery goods and many miscellaneous foods, have now been involved in outbreaks of staphylococcal food poisoning. Staphylococci are widely distributed in nature in association with man and animals and in the environment. They are usually present on the skin, in the mouth and nose, and are frequently the cause of such common infections as boils and pimples. The obvious opportunities for contamination of food through improper handling or accidents and irregularities in processing make staphylococcal food poisoning an actual or potential problem to all industries that handle foods in which staphylococci are able to grow.

Fortunately, not all staphylococcus cultures are of the food poisoning variety. At the present time, however, methods for the identification of food poisoning strains are laborious, expensive and impractical as a routine laboratory procedure. Existing methods require the feeding of suitable preparations of cultures to susceptible monkeys or, more certainly, to human volunteers, or the injection of altered filtrates of cultures into cats. The monkey test is unsatisfactory because of the relative insusceptibility of these animals, the development of resistance and the expense of maintaining a monkey colony. The feeding of human volunteers may not often be resorted to. The cat test also is undesirable owing to the presence of other toxic materials in staphylococcus culture filtrates which without proper care give rise to false reactions, and because of the expense, the seasonal supply, and uncertainty of results. A simple and satisfactory test for the identification of food poisoning varieties of staphylococci is urgently needed. The development of such a test is of great importance to industry in regard to defense in medico-legal cases and in production control. It is of importance to research in providing an adequate tool for study of the nature of enterotoxin and of control measures.

Another concern of the food microbiologist is control of spore-forming bacteria, which are an important cause of spoilage in canned foods. Bacterial spores are resistant to heat and hence persist in underprocessed canned foods. The physiology of the spore is extremely interesting. Following heat shock, *B. subtilis* spores have been shown *(13)* to germinate more rapidly than unheated control suspensions. A brief exposure *(14)* of the spores of *Clostridium acetobutylicum* to boiling temperature caused them to germinate more rapidly. Longer thermal death times have been found for spores of *Clostridium botulinum*, types A and B, and of an unidentified putrefactive anaerobe when recovery cultures were incubated at temperatures of 24°-27° C. than when incubated at 31° or 37° C. Further individual spores from the same culture are not equally resistant to heat *(15)*. An excellent review of this subject with reference to food processing is given by Dr. L. B. Jensen *(16)*.

The above illustrations suffice to show that spores have many interesting physiological properties. It is important that more fundamental studies be made of the physiology of spores. If more information on the properties of spores were available, it is conceivable that measures might be taken to alter the processing procedures of certain foods and thus increase the quality of the product.

In this discussion it has been possible to enumerate only a few of the problems facing food microbiologists. Furthermore, new methods of processing and handling foods are being developed which require careful study. It can be predicted with certainty that the field of food microbiology will be constantly expanding to keep pace with these developments.

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THE REDUCTION OF BACTERIAL COUNT IN EGG PULP BY USE OF GERMICIDES IN WASHING DIRTY EGGS [1]

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The frozen and dried egg industries frequently purchase dirty eggs because of their lower cost; however, the contamination which may arise from the dirty shells of these eggs becomes a vital problem because a low bacterial count is desirable in the finished product. Funk *(1)* has found that better management practices on the farm increased the percentage of strictly clean eggs to not more than 90 percent. On this basis a yearly minimum of two hundred and forty million dozen eggs with soiled shells could be expected in the United States. The fact that a high percentage of the eggs from healthy hens will be sterile on the inside, that is, that contamination is subsequent to laying and not prior to it, has been established by Bushnell and Maurer *(2)*, Mallmann and Davidson *(3)*, Rettger *(4)*, Zagevsky and Lutikova *(5)*, Turner and Arnold *(6)*, and Stuart and McNally *(7)*.

In some plants these dirty eggs have been washed with plain water prior to candling and breaking. Although the washing removes the dirt from the shell surface, it has been determined by Penniston and Hedrick *(8)* that from three to six million organisms still remain on the shell surface of each egg. Susceptibility to bacterial invasion is increased by washing eggs before storing them. This has been demonstrated by Bushnell and Maurer *(2)*, the Committee's Adverse Report published in the *Journal of the Department of Agriculture of Victoria (9)*, Moran *(10)*, and Mallmann and Davidson *(3)*. Therefore, the washing of eggs with a germicidal solution is advocated only when the eggs are to be immediately broken either for drying or for freezing.

EFFECT OF WASHING DIRTY EGGS UPON THE BACTERIAL COUNT OF THE PULP

The purpose of the following experiment was to determine in what degree washing dirty eggs in germicides prior to breaking reduces the bacterial count of the egg pulp and to compare the effectiveness of chlorine and emulsept in this respect. Emulsept is the lauric and myristic acid ester of colamino formyl methyl pyridinium chloride.

Strictly fresh eggs from a supervised farm were used in this series of experiments. Eggs selected at random during the course of the experiments were plated aseptically to determine if the egg meats were sterile, according to the technique recommended in *Standard Methods for Examination of Dairy Products (11)*. One and one-tenth ml. portions of the egg meat were plated in duplicate on glucose tryptone agar. The plates were counted after an incubation period three days at 30° C. The pulp of all the sixty-eight eggs so examined was found to be free of microorganisms.

Thirteen to sixteen separate trials were performed with water, chlorine, and emulsept using the following procedure. For each trial one dozen fresh eggs was artificially contaminated with a mixture of chicken excreta, feathers and straw. Each dozen was washed in 1200 ml. of plain tap water at room temperature. One-half of each dozen was transferred to a jar containing 600 ml. of sterile water. The jars were carefully shaken to swirl the water over the shell surfaces and this rinse water was plated to ascertain the number of microorganisms washed from the shells.

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

The other half-dozen eggs were broken and 600 ml. of sterile water were added to the shells. These shells were pulverized in an electric blender for one minute, and the resulting suspension was plated before the shell particles settled. The egg meats from the half-dozen broken out eggs were placed in 750 ml. sterile Erlenmeyer flasks containing sterile glass beads, shaken well and plated. Since the egg meats were sterile, whatever contamination resulted in the egg pulp would be due to the microorganisms picked up as the egg meat passed over the broken shell surfaces. With chlorine and emulsept the same procedure was followed. The results of these experiments are given in Table 1.

TABLE 1

Bacterial Counts of Dirty Eggs

Trials of one dozen each	Washed in tap water			Washed with chlorine (100 p.p.m.)			Washed with emulsept (0.04%)		
	No. of bacteria per egg × 10^3			No. of bacteria per egg × 10^3			No. of bacteria per egg × 10^3		
	Sterile rinse water	Pulverized shells	Egg pulp	Sterile rinse water	Pulverized shells	Egg pulp	Sterile rinse water	Pulverized shells	Egg pulp
1	115.0	56.7	0.945	55.0	100.0	4.50	41.0	40.0	2.25
2	12.5	116.7	5.37	50.0	600.0	2.25	74.0	340.0	20.25
3	45.0	18.3	0.945	15.0	245.0	2.25	40.0	1550.0	1.35
4	19.5	26.7	7.425	4.0	16.0	0.45	22.0	395.0	4.05
5	55.0	25.0	4.275	130.0	52.0	0.00	6.0	90.0	1.80
6	7.0	20.0	3.735	2.0	21.0	0.00	6.0	70.0	0.45
7	9.0	38.0	19.35	20.0	34.0	1.80	8.0	20.0	1.80
8	40.0	31.6	6.165	21.0	100.0	0.45	20.0	130.0	2.25
9	21.5	26.6	22.50	3.0	50.0	1.80	10.0	6.0	1.35
10	110.0	58.3	36.90	10.0	10.0	1.80	10.0	930.0	1.35
11	165.0	140.0	42.75	4.0	4.0	1.35	6.0	20.0	1.35
12	90.0	80.0	27.00	3.0	3.0	0.90	15.0	1200.0	2.70
13	15.5	78.3	8.55	12.0	12.0	2.25	100.0	54.0	3.50
14	.....	.....	.....	1.0	1.0	1.35	9.0	34.0	2.45
15	.....	.....	.....	3.0	3.0	1.35	7.0	70.0	0.90
16	.....	.....	.....	4.0	4.0	1.35	22.0	52.0	0.90
Average	51.9	55.1	14.30	21.0	134.0	1.49	25.0	306.0	3.04

Both germicides were in contact with the eggs from three to five minutes during the washing period. In this time there was more or less depletion of the active germicidal agent. When only one dozen of these artificially dirtied eggs was washed in chlorine, the amount of available chlorine was reduced approximately 85 percent. Ten trials with an initial content of 150 p.p.m. gave a reduction to 25 p.p.m. When the same type and number of eggs were washed with emulsept, there was only a 23 percent reduction of measurable substance. Twelve trials with an initial concentration of 285 p.p.m. of emulsept gave a reduction to 222 p.p.m.

When no germicide was used in the wash water, equal numbers of bacteria were found by pulverizing the shells or by rinsing the shells in sterile water. However, when a germicide was added to the wash water the one to one ratio no longer existed. With chlorine as the disinfectant, six times as many bacteria were found to be present in the pulverized shells as could be rinsed from the surface of the shells. The average pulverized count using emulsept was twelve times that of the sterile rinse water. A true difference does exist between the counts of the pulverized shells and of the sterile rinse water when the wash water contains a germicide because the difference in the mean counts is more than three times the probable error of the difference. By the same reasoning there is no true difference between the average pulverized shell

counts for emulsept and chlorine even though the pulverized shell count for emulsept is more than twice that of chlorine.

Our only explanation for this considerable increase in the number of organisms obtained on the Petri plates when chlorine and emulsept was used previous to pulverizing the shells is that by some method these substances aid in freeing the organisms from the shell particles. The practical significance of these results is that when some of the recently advocated contact plates are employed to determine the bacterial counts on the egg shells only a portion of the true number of organisms present are revealed.

As indicated in Table 1, the average reduction in numbers of microorganisms on the egg shell was from over 5,000,000 per egg when water was used to 21,000 and 134,000 for chlorine (rinse water and pulverized shell) and 25,000 and 306,000 for emulsept (rinse water and pulverized shell). It is obvious then that with this great reduction in the number of bacteria on the shell surface there should be considerably less contamination in the egg pulp. Without the use of germicide there was an average of 1,500,000 bacteria per egg in the egg pulp. On the other hand, when either emulsept or chlorine was employed the number was reduced to 3000 per egg or less. This means that the use of either of these two disinfectants to wash the eggs would reduce the number of microorganisms in the melange approximately five hundred times.

COMPARISON OF GERMICIDAL EFFICIENCY OF EMULSEPT AND CHLORINE IN WASHING DIRTY EGGS

Since it was found in the preceding experiments that the use of a germicide definitely decreases the bacterial contamination of the egg pulp, the purpose of the following pilot plant experiments was to compare the value of washing large numbers of dirty eggs in solutions of 0.04 percent emulsept and 100 p.p.m. active chlorine.

Eggs used in these experiments were graded at the receiving station as medium to heavy dirty eggs, the shell surfaces of which were covered with soil, chicken droppings, feathers, straw and dried egg pulp.

Each pilot plant experiment consisted of washing six groups, each of twelve dozen dirty eggs, in the same six liters of tap water. After each group was washed, the wash water was plated to determine the bacterial count. From each group of twelve dozen, six eggs were transferred to 600 ml. of sterile water. The water was washed over the surfaces of the eggs and then plated. These counts gave an indication of the number of microorganisms carried over on the surface of each egg from the dirty wash water into the rinse water. Seven pilot plant experiments were done with tap water, which served as a control for the following experiments with chlorine and emulsept. The same procedure was followed when the disinfectants were used, except that eight trials each were made for chlorine and emulsept. It had been found by preliminary experiments that the active chlorine was exhausted after the third group; therefore pilot plant tests were limited to three groups rather than six and eight groups as in the control and emulsept, respectively.

All bacterial counts were determined by plating in duplicate on glucose tryptone agar. The plates were incubated for three days at 30° C. and then counted. The results are given in Table 2.

These data show that after the fourth group with emulsept the percentage of microorganisms killed of those added by a new batch of eggs drops to zero indicating that the wash water no longer contains enough active ingredient to be effective as a germicide. For practical purposes the emulsept wash water could be used safely

until the end of the third group. However, with chlorine even after the first group the percentage of microorganisms killed of those added is less than fifty percent in the wash water which would no longer be an effective germicidal wash.

In seven out of the eight pilot plant experiments with chlorine the amount of active chlorine present after washing the first five dozen eggs of group one was measured. After even this small number of eggs was washed, the chlorine was at the low concentration of 26 p.p.m. Although parts per million chlorine does not necessarily indicate the germicidal efficiency, the solution cannot long remain effective. From these experiments it was found that emulsept is far superior to chlorine as a germicide in washing large numbers of heavy dirty eggs.

TABLE 2

	Successive batches of 12 dozen eggs each	Percent bacteria killed of those added by a new batch of eggs		Concentration at beginning of each batch
		Rinse water	Wash water	
Emulsept 0.04%	1	99.9	99.5	400 ppm
	2	98.7	93.6	280
	3	95.3	97.3	190
	4	92.8	85.6	.....
	5	80.6	0	.....
	6	35.6	3.0	.....
Chlorine 100 ppm	1	92.7	72.4	100 ppm
	2	83.6	46.9	4
	3	29.5	4.0	0.4

Each group of twelve dozen eggs adds approximately 1.5×10^8 bacteria to rinse water and approximately 18.2×10^8 bacteria to the wash water.

CONCLUSIONS

1. It was found that three to six million organisms adhered to the surface of eggs which have been washed in water.

2. When no germicide was used in the wash water, the number of bacteria adhering to the shell surfaces was found to be approximately the same by rinsing or pulverizing the shells in sterile water. However, when either a solution of emulsept (0.04%) or chlorine (100 p.p.m. active) was used to wash the eggs, six to twelve times as many microorganisms were found by pulverizing as by rinsing the shells in sterile water.

3. A 0.04 percent solution of emulsept washed six to ten times as many eggs as could be washed in a solution of 100 p.p.m. active chlorine and yet produce the same reduction in the number of bacteria present on the shell surface and in the wash water.

4. Without a germicide in the wash water there was an average of 1,500,000 bacteria per egg in the egg pulp. When either 0.04 percent emulsept or 100 p.p.m. active chlorine was used to wash the eggs, the number of bacteria in the egg meat was reduced to 3000 per egg or less.

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ENZYME ACTIONS AND FOOD QUALITY[1, 2]

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Enzymes in food products are like ants in the kitchen. The greatest problem they present is how to get rid of them. There is one class of foods from which they cannot be removed. These are the foods which are still alive—such as fresh fruits, viable grains and fresh vegetables. Such materials present one distinct case; the foods composed of dead tissue present another. Sometimes it is found better to kill the tissue and handle it as dead material in order to avoid the complicating physiology. The killing is usually done by a heat treatment.

ENZYME ACTION IN LIVING TISSUE

The case of living tissue applies to fresh fruits and vegetables. What we say may also refer to seeds (such as the grains) but they are too inert to show changes except over long periods.

Even after such living objects become articles of trade, they get ripe, grow old and finally die. There is nothing objectionable in any of these activities as a part of nature; but food technologists are permitted to wish that foodstuffs would not be so quick about it. So in the meantime they are put in an artificial environment—in a cool storage—on the theory that enzyme actions are slower at low temperatures, and therefore the fruit will undergo less change. The success of storage plants testifies that this is so, but that success depends not only on the theory but to a great extent on the detailed conditions of the storage. By definition, an essential condition of a cool storage is the temperature. Low temperatures obviously slow down metabolism, but it is a fair question to ask if that is all that happens. The answer is no.

It should be remembered that the reactions which we generally summarize by measuring oxygen consumption and CO_2 output are not caused by a single enzyme, but by a multitude of enzymes all working together in an attempt to produce a normal metabolism which we are merely trying to slow down. The reactions taking place are consecutive reactions. Amylase converts starch to sugar; sugar is phosphorylated, split into smaller fragments (sometimes triose derivatives), and ultimately oxidized by a long series of consecutive changes. Nature has put many links in the chain of biological oxidation, so that the organism may readily control it, and thus avoid an explosive type of reaction. Herein lies the difference between combustion and biological oxidation. Combustion is like a waterfall, quickly over with; biological oxidation is like a long pipeline, filled with the intermediate products of this series of consecutive reactions.

Under natural conditions, for instance on the tree and in good weather, this series of enzyme actions proceeds smoothly and steadily toward completion. Carbohydrate is oxidized ultimately to CO_2 and water and the fruit receives the energy liberated by the oxidation. The intermediates formed in the chain of oxidative reactions can be disposed of at least as rapidly as they are formed. But each intermediate is disposed of by a separate chemical reaction, and the separate reactions do not have the same temperature coefficients.

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ENZYME ACTION AT ABNORMAL TEMPERATURES

Therefore, if the fruit is placed at an abnormal (for it) temperature, there is a good chance that some of the intermediates will not be disposed of as rapidly as they are formed, and thus will accumulate. There is reason to suppose that among these intermediates are substances of bad odor and bad taste. In addition they may be cell poisons. Their accumulation depresses the quality of the product; may eventually kill it and cause decay.

A well-known example of this situation, in which however the intermediate that accumulates is harmless, is found in the behavior of potatoes stored below 3° C. Such potatoes accumulate sugar because the starch is broken down faster than the sugar is oxidized.

We are indebted to R. Plank *(1)* for expressing this conception in mathematical form, and developing therefrom his theory of cold injury in fruits. If it is assumed that at a low temperature the rate of removal of a poisonous intermediate is slower than its rate of formation, it follows mathematically that there is a temperature at which maximum accumulation of the undesirable substance occurs; and it may be assumed that this is the temperature of maximum deterioration in cold storage.

Such temperatures of maximum injury in cool storage have often been observed. For instance, a distinctly unfavorable temperature (between 1° and 4° C.) has been experimentally determined for the storage of several South African fruits.

The moral to be drawn from this is that no single enzyme is responsible for the spoilage of fruit in cool storage. They are all to blame. In fact, those which have become inactive are perhaps worse offenders than those which still carry on.

THE RESPIRATION OF LEMONS

We are now in possession of much more information about the respiration of fruit than existed when Plank's theory was first proposed. Our laboratory has recently been studying the respiration of lemons, and much more extensive data have lately been published by Haller, Rose, Lutz and Harding *(2)*. Lemons are a good choice for studying fruit respiration because they are harvested according to size and not according to ripeness. It is therefore possible to obtain lemons of all stages of maturity and ripeness from the same plantation and sometimes from the same tree.

The difficulty in subjecting respiration data to mathematical analysis is that individual fruits vary too much. One cannot, for example, reach accurate values for the temperature coefficient of respiration because the variation between different lemons at the same temperature is sometimes greater than the variation between temperature levels ten Fahrenheit degrees apart. In general, however, we know that the respiration coefficient increases as the temperature drops and probably reaches values as high as 4 to 6 in the neighborhood of the freezing point. This is just another example of the fact that biochemical reactions often have temperature coefficients that would be abnormal for straight chemical reactions. Here it simply means that respiration slows down very much when the temperature sinks below that of the natural environment of the fruit.

In spite of the variation between the respiratory rates of individual lemons there is one value that appears to be definitely reliable. This is the respiration quotient: the ratio of the volume of carbon dioxide evolved to that of oxygen taken up. It is obviously independent of the rate of metabolism and depends only on the chemical process that is going on—whether the respiration is due to the burning of carbo-

hydrate or fat or possibly substances of some other class. Fig. 1 shows the relation between the R.Q. values reported by Haller *et al.* *(2)* and the temperature at which the respiration was measured.

Silver lemons are the riper and in this case, as in several others, it has been observed that riper citrus fruits have a somewhat higher R.Q. From this curve, it may be seen that at temperatures which one might consider a normal environment for lemons the R.Q. is practically one, and the presumption is that the fruit is burning carbohydrate with minor variations. This is probably its normal metabolic process.

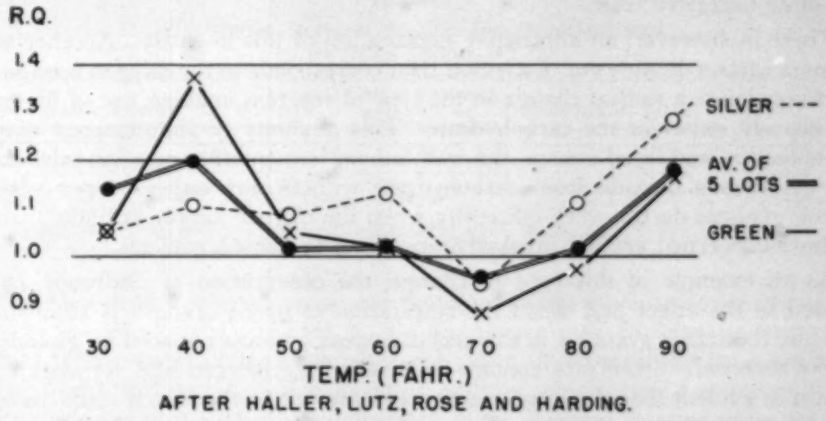

FIG. 1. Showing the variation of the respiration quotient of lemons with the temperature.

When the temperature is either unnaturally high or low the R.Q. is definitely greater than 1. For the low temperature range, with which Plank's theory concerns itself, the R.Q. is about 1.2.*

We may conclude therefore that in the temperature range where damage is apt to occur to the stored fruit something has changed the normal course of metabolism, so that more carbon dioxide is evolved than corresponds to the amount of oxygen taken up.

The first question to arise is whether this fact does not completely upset the theory that there is an accumulation of partly oxidized carbohydrate residues in the tissue. On the face of it, such a situation should call for a decreased output of carbon dioxide, and on experiment we have found the reverse.

ALTERNATIVE EXPLANATIONS

Perhaps no accumulation does occur. But if this is the case, there must be an oxidation of the already partly oxidized carbohydrate in the fruit. This would correspond to emptying the pipeline of carbohydrate oxidation from the point where the stoppage has occurred. If this is so, there must be a great deal of material to be disposed of, for respiratory processes in stored citrus fruits are able to go on for many days without essential change, except perhaps minor ones in velocity. Nevertheless, this explanation appears to be the one accepted by many people who consider that the stored up citric acid and similar highly oxidized substances are now undergoing oxidation that did not occur at higher temperatures.

* It is presumed that the fruit respired in the absence of strong light or otherwise the matter of photosynthesis should be considered. When photosynthetic processes take place, the observed R.Q. of the overall reaction is naturally much lower than would otherwise be the case.

The trouble with this explanation is that a very considerable amount of CO_2 must be accounted for and the many analyses for acids made on citrus fruits during storage do not show a sufficient decrease to account for the extra carbon dioxide being given off.

Nevertheless, the explanation is a logical possibility and the substance that is disappearing from fruit may not have been accurately measured or even recognized. This is particularly true because, as I shall show presently, practically all the respiration occurs in the peel and not in the fruit itself. Perhaps we should look again for what is missing in the rind of a cool-stored lemon that is present in the rind of an untreated fruit.

There is, however, an alternative explanation of this anomaly. Another way to get more carbon dioxide out of a lemon than corresponds to the oxygen used to make it is to postulate a radical change in the type of reaction, making use of the oxygen that already exists in the carbohydrate. This amounts to simultaneous oxidation and reduction and is, of course, the well-known fermentation reaction whereby one may get carbon dioxide from carbohydrate without any oxygen input whatever. Microorganisms do this very efficiently when the oxygen supply is limited, and the reactions concerned are not necessarily confined to microorganisms.

As an example of this type of change, the observation of Dufrenoy *(3)* can be cited to the effect that when the respiration of green oranges is stimulated by ethylene, the starch granules in the peel disappear and are replaced by globules of a fat-like material. Since fats contain relatively little oxygen and terpenes contain none, it is evident that the oxygen originally present in the starch could have been available for oxidative purposes. The result of such a reaction would be the accumulation of some substance in a relatively low state of oxidation, probably a substance of considerable reducing capacity.

The difficulty confronting this hypothesis is exactly the same as that mentioned for the first one: we have no evidence of the accumulation of the substance whose existence we must postulate. The quantities involved are really so large that it seems incredible that they have been missed. For example, the respiration rate of a green lemon at 40° F. is about 7 milligrams of carbon dioxide per kilo per hour, or well over a gram of CO_2 per week. To account for an R.Q. of 1.2 (and this is a conservative figure at 40°), one must have an evolution of 5 cc. of CO_2 for an intake of 4 cc. of oxygen. In other words, one-fifth of the CO_2 evolved must be formed by some other process than normal carbohydrate oxidation. This would require the formation of nearly 250 mg. of alcohol per kilo per week or of about 135 mg. of ethylene or a terpene, to take possibilities at random that illustrate the point. Furthermore, the accumulated substance should be found concentrated in the peel rather than distributed throughout the whole fruit. Of course, no such quantity of ethylene is produced and, according to Trout and his co-workers *(4)*, the most we can expect in the way of alcohol is less than a third of this quantity.

We are therefore faced with two possibilities, both of which at the present explain the known facts. The fruit in cold storage has either lost an easily measurable quantity of something whose identity we do not know, but which must be a highly oxidized substance; or it has accumulated a correspondingly large amount of unidentified material which must be a highly reduced substance. This does not decide the question, but it certainly points out a line of endeavor along which more work might well bring definite answers that ought to be of considerable use in the storage of fruits and similar living objects.

EFFECT OF MECHANICAL INJURY

Before leaving the subject of enzyme actions in living things, I would like to point out one of the pitfalls which await the investigator, and suggest a possible explanation for some of the great variations between separate samples of fruit. Not only citrus fruit, but many, if not most, agricultural products are extremely sensitive to mechanical injury on the surface. This injury stimulates the output of carbon dioxide enormously. Two examples from the work of our laboratory are shown in Table 1. One is taken from some observations on the curing of vanilla.

TABLE 1

Respiration Response to Skin Injury as Indicated by Increased Output of CO_2

Green vanilla beans 25° C.	Before units CO_2	After units CO_2	Percent on original	Green lemons 25° C.	Units CO_2	Percent on original
Rubbed with 50 percent alcohol	47	58	124	Whole	70-80	100
Dipped in water at 80° C.	47	81	172	Peeled	95	127
Three lengthwise scratches	86	168	196	Peelings	348	465

The first step in this process, as handed down for centuries, is to cause some slight injury to the skin of the so-called bean. The injury may be done by momentary exposure to hot water or by scratching with a pin or by pinching the bean in the fingers. The resulting burst of respiratory activity which these treatments induce is quite evident, but it is mild in comparison to the increase in respiration rate of a lemon rind when it is peeled off the fruit. The lemon experiment told us two things. The peeled lemon showed almost the same respiratory rate as the whole fruit, although the injury must have increased this rate somewhat. We concluded that the inside of the fruit had very little to do with respiration as ordinarily observed on the whole fruit. On the other hand, the purely mechanical injury has increased the respiration of the peel nearly 5 times. In the presence of atmospheric oxygen, I would not regard fresh lemon peel as a good thing to store in bulk unless a considerable heat effect is desired.

ENZYME ACTION IN DEAD TISSUE

We may now consider the case of food tissue that has been purposely killed to destroy the enzymes that cause quality loss. If the destruction was really accomplished, there is no longer an enzyme problem to discuss. However, the conditions used to kill tissue are deliberately selected as the mildest, in order to cause the least injury to the material; so they do not always achieve their purpose of completely destroying all enzyme activity.

The only practical means in use today for destroying enzyme action are heat and some forms of chemical impregnation for example, the use of sulfur dioxide. Of these, heat treatment is the most commonly used and the problem that it presents to the food technologist is usually not how far he can go, but how soon he may stop. The answer varies largely with what the fate of the product is to be; whether it shall reside in the tropics or in the polar regions. Frozen foods obviously need a different processing from dried foods; but, in either case, blanching is the penalty one pays to get rid of enzyme action. The aim is to pay no more than is necessary. Such inhibitors as sulphite appear at times to be of good service in reducing the amount of heat treatment required. On the other hand, it is easily demonstrated that

insufficient blanching may be worse than none. Unskillfully applied, heat may disrupt the tissues and still leave the enzyme proteins intact, to work even more efficiently than in natural tissue where they are at least restricted to certain cells.

Thus tests for inadequate blanching are important and these tests have been very properly centered around certain enzymes whose heat resistance is above the ordinary. Peroxidase has become much more important as a test for blanching than it probably is as a cause of deterioration. There is some reason to think that peroxidase and enzymes like it are concerned directly with the darkening of food products, but they are probably quite unconcerned with other forms of quality failure.

In spite of better methods for blanching and better techniques for measuring its completeness, one phase of the process will always offer a difficult problem to the food technologist. The penetration of heat into the object requires a finite time, and in the case of large objects this time is not a small interval. While the object is being warmed up, the conditions for enzyme action are at their optima, so that any lengthening of the heating period beyond what is absolutely necessary leads to an enzymically altered product. This result may at times be very pronounced. I am reminded of an example published long ago by Magoon and Culpepper *(5)* who studied the changes in sweet potatoes on scalding. Table 2 is taken from their data.

TABLE 2

Content of Reducing Sugars in Sweet Potatoes

	Uncooked	Cooked 35 min. in steam
	pct.	*pct.*
Fresh	2.26	8.19
	1.86	8.55
Stored 30 days	4.52	13.67
	4.14	11.11

After Magoon and Culpepper.

The great amount of starch that changed to sugars during the scalding period is impressive. It indicates, moreover, that sweet potatoes should contain an unusually large amount of amylase. Recent work at the Western Regional Research Laboratory has proved that they do. Our laboratory also looked into this problem and found that the enzyme is beta-amylase, and that it occurs in a quantity greater on a dry basis than in wheat flour or in malt. Sweet potatoes are, therefore, one of the richest known sources of beta-amylase, and sweet potato juice may some day find practical application for the reason that poor malt is usually poor in beta and not in alpha-amylase. Poor malt fortified with beta-amylase is generally much improved.

POSSIBLE ROLE OF AMYLASE

In starch-containing products (such as the sweet potato) the amylase is the enzyme of first attack in the metabolic cycle. Through it the inert starch is made into chemically active sugar which subsequently undergoes oxidation or fermentation. A study of the properties of this enzyme is therefore indicated if one desires to start at the beginning in tracing the respiration of agricultural objects. If we knew how to stop the respiration at the beginning of the process, it might save a lot of headaches.

In the hope that we may be able to make a contribution to the future knowledge of amylase and its action on starch, we have studied the purification of this enzyme

from sweet potatoes and have recently succeeded in crystallizing an amylase from this source. The crystals of the enzyme are rather large and unusually well-formed for protein crystals, and I take pleasure in showing you a picture of them (Fig. 2) publicly for the first time.

FIG. 2. Crystals of beta-amylase of sweet potatoes.

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THE BLANCHING OF VEGETABLES BY ELECTRONICS [1, 2]

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Recently the consuming public has been increasingly conscious of the nutritive qualities of processed foods. Whenever studies have been made of the changes in the nutritive value of vegetables during processing, it has been found that, in the case of the water-soluble vitamins, a considerable portion is removed in the blanching operation. These losses of the water-soluble vitamins, such as vitamin C, have been caused by the leaching action of the hot blanching water or steam condensate. Therefore, any process in the preservation of foods, such as blanching, that causes losses of water-soluble vitamins should be investigated with the object of modifying or changing that process so that these vitamin losses are largely overcome or eliminated.

The advent of high frequency electricity for the commercial dielectric heating of non-conductors in the preforming of plastics and the bonding of plywood has called attention to the possible value of this agency for the blanching of vegetables without an accompanying change in nutritive value. Moreover, it should be possible to expose the vegetable to less heat to achieve the same internal temperature because in dielectric heating the heat is generated uniformly throughout the mass and excessive external heating is not required for adequate penetration. A further advantage of dielectric heating seemed possible in the blanching of vegetables prior to freezing in that the washed, prepared material could be dielectrically heated in the final retail cartons and thus avoid some handling.

Preliminary experiments on the blanching of peas, diced carrots and potatoes were conducted with oscillators operated at 7 to 10 megacycles. When sufficient power was applied to the electrodes, arcing or burning occurred between the upper electrode and the vegetable and between the individual vegetable particles. A 30 megacycle oscillator was also tried with the same vegetables and the incidence of burning was somewhat lessened. It seemed, then, that the arcing was due to high voltages at the electrodes and that to maintain the same power output, the frequency would have to be increased if the voltage were decreased. Further experiments, using an oscillator operating at a frequency of 150 megacycles, demonstrated that this contention was correct.

During the past season, a variety of vegetables have been blanched with dielectric heating. The oscillator used in this investigation is an experimental unit and was constructed in the R. C. A. Laboratories at Princeton, New Jersey. It is a self-excited oscillator, using a pair of Eimac 304-TH tubes in push-pull, with a possible power output of 750 watts at 150 megacycles. The arrangement of the apparatus may be seen in Figs. 1 and 2. In the early experiments at the lower frequencies, it was found that the vegetable in the center of the carton heated more rapidly than that nearer the outside. This non-uniformity in heating was caused by a heat loss from the sides of the carton and could be overcome by placing the electrodes in an air oven maintained at 212° F. (100° C.). At first, considerable difficulty was encountered in loading the oscillator so that the vegetable mass was rapidly heated. Correct coupling of the oscillator to the load is more difficult at higher frequencies

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and in this instance was achieved by the use of tuning stubs as recommended by Bierwirth and Hoyler *(1)*. In the apparatus shown, the tuning stubs were not readily adjusted and it was difficult to heat successive cartons of a vegetable packed in apparently the same manner but where the electrical characteristics were different. A flexible tuning arrangement was obtained by raising or lowering the upper electrode and thus compensating for an unsuitable inductance of the tuning stubs. Care was taken to avoid the occurrence of jagged edges and the use of metals other than copper or brass in the connections between the electrodes and tank circuit of the oscillator.

FIG. 1. Experimental radio frequency generator used in vegetable blanching experiments.

In practice, the washed, prepared vegetable was placed in the cellophane liner of an end-opening carton and the carton centered between the electrodes with the aid of glass rods. With the first of a series of cartons of the same vegetable, the oscillator was roughly coupled to the load and the closer tuning accomplished by movement of the upper electrode. The adequacy of the tuning was indicated by the meters giving the plate voltage, plate current and grid current of the power tubes. The temperature of the product was measured with a thermometer, the bulb of which was inserted to the center of the carton. In the temperature range of 170° to 190° F., the thermometer readings tended to lag behind the vegetable temperature. A thermocouple with a choke coil *(1)* before the potentiometer was tried but the readings were very erratic and it was difficult to effectively shield the potentiometer from this very high frequency electricity. When the desired temperature was reached, the carton was removed from the oven and placed on the refrigeration coils of a —10° F. cold room. Analyses were made of the blanched frozen vege-

tables for their ascorbic acid and carotene contents. The catalase, peroxidase, lipoxidase and ascorbic acid oxidase activities of the frozen vegetables were also determined.

A comparison was made of the effects of water, steam and electronic blanching on Thomas Laxton peas. A quantity of peas having a tenderometer reading of 86 was washed, sorted and thoroughly mixed to insure uniformity. Portions of this batch of peas were then blanched for different intervals in steam and boiling water and at different temperatures electronically. The results of the enzyme activity studies are presented in Table 1.

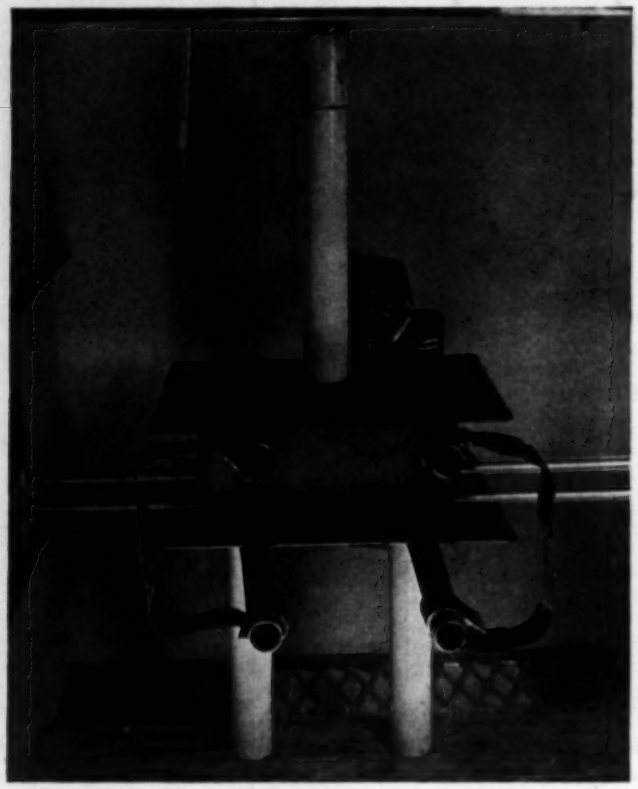

FIG. 2. The carton was centered between the electrodes with the aid of glass rods.

The results of the enzyme activity studies indicate that catalase, ascorbic acid oxidase and lipoxidase are much more heat-sensitive than peroxidase. The thermostability of peroxidase was apparently greater in the electronically blanched samples though this difference may be due to leaching of an interfering compound in some of the water and steam blanched samples. Catalase activity, which is often used as a criterion of blanching adequacy, was inactivated when the electronically heated peas reached a temperature of 170° F.

The preparation and blanching of the various samples of peas with the limited power of the experimental oscillator involved considerable time, and it was not possible to determine the ascorbic acid and carotene contents of the samples immediately after blanching. The ascorbic acid and carotene analyses were performed on the blanched samples after they had been frozen and stored a few days at —10° F.

TABLE 1

Enzyme Activity of Peas Blanched in Different Ways

Blanching medium	Blanching temperature in °F.	Blanching time in minutes	Catalase	Ascorbic acid oxidase	Lipoxidase	Peroxidase
Unblanched	.....	.....	++++	+	+	++++
r.f. power	160	0	+	+	—	++++
r.f. power	170	0	—	+	—	++++
r.f. power	180	0	—	+	—	++++
r.f. power	190	0	—	+	—	+++
r.f. power	200	0	—	—	—	++
r.f. power	210	0	—	—	—	+++
Water	210	0.3	±	+	—	++++
Water	210	1.0	—	+	—	++
Water	210	3.0	—	—	—	—
Steam	210	0.5	±	+	—	++++
Steam	210	1.5	—	—	—	++
Steam	210	3.0	—	—	—	—

TABLE 2

The Ascorbic Acid Content of Frozen Blanched Peas

Blanching medium	Blanching temperature in °F.	Blanching time in minutes	Ascorbic acid content in mg./gm.
r.f. power	160	0	0.13
r.f. power	170	0	0.14
r.f. power	180	0	0.15
r.f. power	190	0	0.22
r.f. power	200	0	0.22
r.f. power	210	0	0.21
Water	210	0.3	0.17
Water	210	1.0	0.19
Water	210	3.0	0.15
Steam	210	0.5	0.17
Steam	210	1.5	0.18
Steam	210	3.0	0.19

TABLE 3

The Carotene Content of Frozen Blanched Peas

Blanching medium	Blanching temperature in °F.	Blanching time in minutes	Carotene mcg./gm.
r.f. power	160	0	3.33
r.f. power	170	0	3.59
r.f. power	180	0	3.68
r.f. power	190	0	3.65
r.f. power	200	0	3.85
r.f. power	210	0	3.96
Water	210	0.3	3.31
Water	210	1.0	3.29
Water	210	3.0	4.00
Steam	210	0.5	3.73
Steam	210	1.5	3.75
Steam	210	3.0	3.69

In Table 2 are presented the results of the ascorbic acid analyses. It may be noted that the samples adequately blanched by r.f. power possess the highest ascorbic acid contents. When the application of r.f. power was insufficient, there was considerable loss of ascorbic acid during even brief storage. The somewhat lower values occurring in the water and steam blanched samples as compared to the optimal r.f. blanching condition may be attributed to leaching of the water soluble vitamin. The variously blanched samples have also been examined for their ascorbic acid contents after a six months' storage period, and small losses of ascorbic acid were noted independent of the method of blanching. The results of the carotene analyses, which are presented in Table 3, show little significant difference between the samples blanched optimally by r.f. power, water or steam. Underblanched samples, regardless of the blanching method used, lost considerable carotene even during the short frozen period.

COLOR AND FLAVOR EVALUATION OF STORED FROZEN PEAS

All of the frozen samples were cooked for a standard time of six minutes and a panel of six people were asked to score the flavor and color of the cooked samples. The scores consisted of: 1 for very good, 2 for good, 3 for fair, 4 for poor, and the individual scores were averaged. These are presented in Table 4. The superior

TABLE 4

Organoleptic Examination of Pea Samples After Six Months' Storage at —10° F.

Blanching medium	Blanching temperature in °F.	Blanching time in minutes	Flavor rating	Color rating
r.f. power	160	0	3.0	1.6
r.f. power	170	0	2.6	1.9
r.f. power	180	0	2.4	1.9
r.f. power	190	0	2.4	2.1
r.f. power	200	0	2.6	2.1
r.f. power	210	0	2.4	2.7
Water	210	0.3	1.3	1.0
Water	210	1.0	1.6	1.0
Steam	210	1.5	1.4	1.0

color and flavor of the water and steam blanched samples over those blanched by r.f. power was an unexpected finding, since in preliminary studies an examination of the products immediately after blanching had revealed a satisfactory product and the enzyme tests had shown a complete inactivation of catalase. It came to mind that a fundamental difference in blanching might be in the inadequate rapid cooling of the packaged product after r.f. blanching. It was decided to test this point with a vegetable that was available during the winter months, namely potatoes.

Towards this end, potatoes were peeled, diced and blanched in the carton with r.f. power. Some samples were analyzed immediately after blanching, the contents of some cartons were emptied on a tray before a fan at —10° F., and other samples cooled in the carton at —10° F. in the same manner that the peas had been cooled. After a half hour the sample on the tray was analyzed for its ascorbic acid content and a similar analysis was performed on the samples cooling in the carton. The temperature of the sample cooled in the carton was approximately 40° F. after three hours, while the diced potatoes on the tray were frozen within the half hour period. The results of these ascorbic acid analyses are presented in Table 5.

It may be noted that there is a marked loss of ascorbic acid from the blanched potatoes that had been slowly cooled in the carton, while little loss occurred upon rapid cooling of the product. It seems very probable, therefore, that a similar inadequate cooling occurred in the samples of peas blanched with r.f. power, and this may have resulted in a deterioration of quality with regard to flavor and color. The ascorbic acid retention of the electronically blanched peas might have been even more superior to those blanched in steam and water if provision had been made for rapid cooling. In this connection it may be recalled that in a previous publication *(2)* all of the ascorbic acid was retained in the r.f. blanching of cabbage as compared to the 30 and 40 percent loss during steam and water blanching. In this instance the analyses were made immediately after the heat treatment, and the factor of the rate of cooling did not enter the study.

TABLE 5

Loss of Ascorbic Acid During Electronic Blanching of Potatoes and After Slow and Fast Cooling

	Ascorbic acid content mg./gm.	Percent loss of ascorbic acid
Unblanched	0.092	---
r.f. blanched 3 min. at 212° F.	0.086	7
r.f. blanched 3 min. at 212° F. and cooled on tray in slow air movement at —10° F.	0.092	0
r.f. blanched 3 min. at 212° F. and cooled in carton at —10° F.	0.033	64

SUMMARY

It has been found feasible to blanch a variety of vegetables by electronics with a favorable retention of ascorbic acid and carotene. Unless adequate provision can be made for rapid cooling of the blanched material in the carton, it would seem necessary to us to adopt other methods of applying r.f. power such as by placing the material on a belt and, immediately after blanching, removing the heat in a refrigerated air stream. Experiments will be continued in this direction.

ACKNOWLEDGMENT

We are indebted to the R. C. A. Laboratories for loan of the experimental oscillator, to Mr. W. T. Tapley for the vegetables used in this study, and to Dr. W. B. Robinson for his assistance in the blanching operations and enzyme activity determinations.

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THE EFFECT OF VARIOUS COOKING METHODS ON THE VITAMIN RETENTION IN VEGETABLES, THIAMINE AND ASCORBIC ACID[1]

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Vegetables may be cooked by a variety of methods, depending upon personal preference and the experience of the housewife. Methods include boiling in a large amount of water (one to two cups for four servings); boiling or steaming in a small amount of water (one third to one half cup for four servings); steaming in regular steamers; baking, and cooking under steam pressure. In recent experiments *(1, 4, 7)* vegetables retained more ascorbic acid in the vegetable itself when cooked in a pressure saucepan than when boiled or steamed. Boiling meant cooking a four-serving portion of each vegetable in one cup or approximately 250 grams of water. Recommendations accompanying pressure saucepans suggest cooking vegetables in relatively small amounts of water. This study was undertaken to find out if the retention of water-soluble vitamins, notably ascorbic acid and thiamine, in the vegetable itself during cooking is dependent primarily upon the use of steam pressure or upon the amount of water used.

McIntosh, Tressler and Fenton (1940) reported several quick frozen vegetables retained the highest percentage of ascorbic acid when cooked in a pressure saucepan. The destruction of ascorbic acid by all methods was small, being less than 15 percent, except with the 12-quart standard pressure cooker. Data from several investigators, including McIntosh, Tressler and Fenton *(2)*, Barnes, Tressler and Fenton *(3, 4)*, Ireson and Eheart *(5)*, Gleim, Tressler and Fenton *(6)*, indicate clearly that retention of the water soluble vitamins is inversely proportional to the amount of cooking water used. In one report by Brinkman, et al. *(7)*, the exact amounts of water used in cooking vegetables under different condition were not stated but retention of ascorbic acid was higher in four out of six vegetables cooked in a pressure saucepan.

In this study several vegetables, fresh and frozen, were cooked on the surface units of an electric range in a small amount of water, under different pressures, 0 to 20 pounds, in a stainless steel pressure saucepan, and in the range oven in a pyrex casserole. Previous work *(2)* had shown that the composition of the cooking utensil had no effect on ascorbic acid retention in quick frozen vegetables, thus any differences obtained between cooking in stainless steel and in pyrex are assumed in this study to be more dependent on the cookery methods used than upon the composition of the utensil. Vegetables of a known variety were grown in our experiment garden. Details of the cooking methods employed are summarized in Table 1. The frozen vegetables were blanched and frozen in the laboratory. Values reported represent averages obtained when five to seven lots of each vegetable were cooked by exactly the same method. Average deviations from the means were calculated and recorded for the retention in the vegetable itself. The various pressures employed were regulated by a gauge and weights devised in our engineering department. The pressure saucepan was a 4-quart stainless steel model with flex-seal type closure. One-quart covered pyrex casseroles were used in oven cookery and a standard cooking period, 60 minutes, was used for each vegetable as this period, or longer, is generally allowed in oven meals.

Thiamine and ascorbic acid assays were made before and after each cooking and the percentage retention in vegetable and liquid calculated on the basis of the fresh

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.
[2] Present address is Frozen Food Foundation, Inc., Syracuse, N. Y.

TABLE 1

Vegetable Cooking Methods

Vegetable variety	Pressure	Utensil	Cooking time		Vegetable	Water
			Precook	Cook		
	lbs. gms. per sq. in.		*min.*	*min.*	*gms.*	*gms.*
Cabbage	0	Stainless steel	2.8	5.0	300	50
Jersey	5	Stainless steel	3.3	3.0	300	50
	10	Stainless steel	3.7	2.0	300	50
	15	Stainless steel	4.0	1.0	300	50
	20	Stainless steel	4.2	0.0	300	50
Green beans	0	Stainless steel	3.7	12.0	400	100
Tendergreen	5	Stainless steel	4.2	8.0	400	100
	10	Stainless steel	4.6	6.0	400	100
	15	Stainless steel	4.7	4.0	400	100
	20	Stainless steel	5.1	2.0	400	100
Same frozen	0	Pyrex casserole	5.0	60.0	400	0
Lima beans	0	Stainless steel	3.2	15.0	300	100
Fordhook	15	Stainless steel	3.0	5.0	300	50
Same frozen 7 mos.	0	Stainless steel	4.5	12.5	400	100
	15	Stainless steel	5.5	2.5	400	50
	0	Pyrex casserole	6.0	60.0	400	50
Parsnips	0	Stainless steel	3.0	5.0	300	100
Harris Model	5	Stainless steel	2.0	3.0	300	100
1944	10	Stainless steel	2.6	2.0	300	100
	15	Stainless steel	3.5	1.0	300	100
	20	Stainless steel	4.2	0.0	300	100
Parsnips	0	Stainless steel	3.8	5.0	400	125
Harris Model	15	Stainless steel	5.0	1.0	400	125
1945	0	Pyrex casserole	9.0	60.0	400	50
Peas	15	Stainless steel	4.5	0.5	300	50
Thomas Laxton						
Same frozen 7 mos.	0	Stainless steel	3.5	4.0	400	30
	15	Stainless steel	5.8	0.25	400	30
Rutabagas	0	Stainless steel	3.2	12.5	400	65
Improved Long Island	15	Stainless steel	4.2	2.5	400	65
	0	Pyrex casserole	10.0	60.0	400	50

or frozen vegetable. For ascorbic acid assays one hundred grams cooked or raw vegetable were ground with 3 percent metaphosphoric acid in a Waring blendor and the volume made up to 500 milliliters. Portions of the extract were centrifuged and aliquots titrated with 2, 6 dichlorobenzenone-indophenol, as in the original Bessey and King *(8)* method. One third of the remaining cooking liquid, by weight, was made up to 100 ml. with 3 percent metaphosphoric acid and aliquots titrated.

One third of the cooked vegetables, by weight, or one hundred grams of the raw vegetables, was ground with .08N sulfuric acid in a Waring blendor and the thiamine determined by the method of Conner and Straub *(9)*. One third of the remaining cooking liquid, by weight, was extracted for thiamine.

Three vegetables, cabbage, green beans, and parsnips, were cooked under 0, 5, 10, 15 and 20 pounds pressure and the effect on the ascorbic acid content determined, Table 2. In cabbage the ascorbic acid destruction was apparently independent of the pressure used, being 10-16 percent. In green beans, showing 7-20 percent destruction of ascorbic acid, the destruction was apparently independent of the pressure above 10 pounds, but there was appreciably less destruction as the pressure

was decreased below 10 pounds. In parsnips, showing 5-28 percent destruction of ascorbic acid, the destruction was appreciably greater as the pressure was increased. In all cases the amount leached into the cooking water was small, being less than 10 percent.

TABLE 2

Effect of Cooking[1] at Different Pressures on the Ascorbic Acid Retention in Vegetables

Pressure	Cabbage		Green beans		Parsnips	
	Ascorbic acid in		Ascorbic acid in		Ascorbic acid in	
	Vegetable	Liquid	Vegetable	Liquid	Vegetable	Liquid
	percent	*percent*	*percent*	*percent*	*percent*	*percent*
0	87.1 ± 5.5	2.1	82.9 ± 6.5	9.9	89.3 ± 7.9	6.0
5	81.8 ± 4.6	7.8	78.8 ± 5.3	9.8	82.4 ± 3.5	7.0
10	79.9 ± 3.6	7.1	72.9 ± 4.9	7.9	74.5 ± 5.4	7.2
15	78.7 ± 5.8	8.2	71.4 ± 3.6	9.1	64.1 ± 3.2	7.9
20	75.8 ± 0.4	7.9	72.5 ± 3.8	9.2	67.9 ± 5.2	6.9

[1] Values reported represent averages from 5 to 7 tests in each case.

TABLE 3

Relative Retention of Ascorbic Acid in Vegetables Cooked[1] Under Atmospheric and Fifteen Pounds Pressure

Vegetable	Atmospheric pressure		15 pounds pressure	
	Ascorbic acid in		Ascorbic acid in	
	Vegetable	Liquid	Vegetable	Liquid
	percent	*percent*	*percent*	*percent*
Cabbage	87.1 ± 2.4	1.6	78.7 ± 2.6	8.2
Green beans	78.6 ± 3.1	9.0	71.4 ± 5.0	9.0
Lima beans (frozen)	78.0 ± 3.4	12.7	82.4 ± 2.2	7.1
Parsnips (1943)	89.3 ± 3.3	6.0	64.1 ± 4.5	7.9
Parsnips (1944)	90.1 ± 2.3	7.2	77.5 ± 2.9	6.1
Peas (frozen)	82.7 ± 2.0	11.2	86.2 ± 0.6	10.7
Rutabagas	81.2 ± 3.6	7.4	80.5 ± 3.8	8.9

[1] Values reported represent averages from 5 to 7 tests in each case.

In Tables 3 and 4 cooking vegetables under 15 pounds pressure is contrasted with cooking under atmospheric pressure. Lima beans cooked under atmospheric pressure required more water due to the evaporation during a longer cooking time and this resulted in a greater leaching of both thiamine and ascorbic acid from the beans into the cooking water. The actual destruction of thiamine in all cases was very small, and in most cases within experimental error. Ascorbic acid destruction varied from 3 to 12 percent when the vegetables were cooked under atmospheric pressure and from 3 to 20 percent, except one series of tests on parsnips, when the vegetables were cooked under fifteen pounds pressure. In the present study all cooking was done in a small amount of water, and under such conditions cooking under atmospheric pressure retained as much or more ascorbic acid in the vegetable itself. In previous studies *(1)* and *(7)*, where cooking in pressure saucepans under 15 pounds pressure was compared with cooking under atmospheric pressure the volume of water used in the latter method was far in excess of the amount used in the present study and consequently the better retention of ascorbic acid in vegetables cooked in the pressure saucepan can be interpreted, in part, as due to the small volume of water used, rather than to the pressure.

Because cooked vegetables are not widely recognized as a source of ascorbic acid and much that remains after cooking has been assumed to be in the cooking water,

it is important to realize that vegetables cooked quickly in a small amount of water in a covered saucepan retain 78 to 90 percent of the original ascorbic acid in the vegetable itself (Table 3). Slightly lower values were obtained in some vegetables cooked under pressure. Thiamine in vegetables is not easily destroyed when proper cooking methods are employed, although a considerable amount may be leached into the cooking water, depending on the vegetable, amount of water, and length of cooking time (Table 4).

TABLE 4

Relative Retention of Thiamine in Vegetables Cooked[1] Under Atmospheric and Fifteen Pounds Pressure

Vegetable	Atmospheric pressure		15 pounds pressure	
	Thiamine in		Thiamine in	
	Vegetable	Liquid	Vegetable	Liquid
	percent	*percent*	*percent*	*percent*
Cabbage	87.2 ± 4.8	1.7	93.9 ± 6.5	6.4
Lima beans (fresh)	74.1 ± 2.4	22.0	84.0 ± 1.2	6.0
Lima beans (frozen)	84.2 ± 11.3	13.6	88.0 ± 10.3	10.4
Peas (frozen)	100.9 ± 5.4	9.5	98.2 ± 3.2	7.7
Parsnips	103.0 ± 9.0	5.0	98.2 ± 8.4	6.1
Rutabagas	95.2 ± 7.3	8.2	96.1 ± 8.1	9.9

[1] Values reported represent averages of 5 to 7 tests in each case.

TABLE 5

Effect of Casserole Cookery[1] on the Thiamine and Ascorbic Acid Content of Vegetables

Vegetable	Thiamine retention		Vitamin C retention	
	Solid	Liquid	Solid	Liquid
	percent	*percent*	*percent*	*percent*
Lima beans (frozen)	94.8 ± 11.6	....	81.6 ± 4.1	....
Parsnips	91.7 ± 3.0	....	40.0 ± 4.9	....
Rutabagas	.....	....	61.4 ± 5.1	....
Green beans (frozen)	97.2 ± 7.2	9.0	52.5 ± 6.6	5.3

[1] Values reported represent averages of 5 to 7 tests in each case.

The longer time oven casserole cooking resulted in large losses of ascorbic acid for parsnips, rutabagas and green beans but not for frozen lima beans (Table 5). Lima beans, parsnips, and rutabagas absorbed all the added water which did not evaporate during cooking, but considerable liquid remained when the frozen green beans were cooked, although no water was added. The thiamine in the vegetables investigated was apparently stable during casserole cooking.

SUMMARY

Several vegetables, fresh and frozen, have been cooked (1) under atmospheric pressure in a small amount of water, (2) under various pressures, and (3) in a casserole. Assays for thiamine and ascorbic acid were made before and after cooking.

In most vegetables the actual destruction of ascorbic acid during cooking in standard or pressure saucepans was 15 percent or less. Sixty-four to 90 percent of the original ascorbic acid was retained in the vegetable itself. In most instances the amount found in the vegetable was 80 percent or more of the original content.

Fresh vegetables tested retained more ascorbic acid when cooked under atmospheric pressure than when cooked under 15 pounds pressure. Frozen lima beans and peas retained 3.5 to 4.5 percent more ascorbic acid when cooked under 15 pounds

pressure, although the destruction in each case was approximately the same. The larger amount of ascorbic acid in the liquid accompanying the lima beans cooked under atmospheric pressure may in part have been due to the larger amount of cooking water necessary and the longer cooking time. Very little if any thiamine was destroyed in any of the methods investigated.

Casserole cookery destroyed a large part of the ascorbic acid in rutabagas, parsnips and green beans, where cut surfaces of the vegetable were exposed during cooking.

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EFFECTS OF A TRYPTOPHAN-DEFICIENT DIET SUPPLEMENTED WITH VITAMIN E ON THE GROWTH AND ON THE VITAMIN A STORES OF RATS [1, 2, 3]

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Conditions which influence the storage of vitamin A and its disappearance in the body are poorly understood. It is asserted that the tocopherols may delay loss of vitamin A from the stores. It is believed by some that vitamin A may be carried in the body in association with proteins; it may possibly be stored in association with them.

The experiments to be reported deal with the influence upon vitamin A stores of the rat of: (1) a derangement of protein metabolism brought about by the absence in the diet of an essential amino acid, tryptophan; (2) the effect of additions of mixed tocopherols to the diet of animals with tryptophan deficiency.

Studies concerning the effect of the tryptophan-deficient diet on the formation of antibodies and serum proteins by the rats are included because it is believed that the formation *(1)* of antibodies is influenced by the protein reserves of the organism.

THE EFFECTS OF THE TRYPTOPHAN-DEFICIENT DIET ON THE VITAMIN A STORES OF RATS

Fifty-nine 3-4 week-old rats, the mothers of which had received only Purina dog chow diet, and to which the Purina dog chow diet was available as soon as they were old enough to eat, were given by mouth 1 drop of fish liver oil which contained 4,200 International Units of vitamin A. No more vitamin A was given during this or the following experiments. It was considered that 24 hrs. later the vitamin A stores of the rats would be approximately uniform. The rats were then divided as fairly as possible in respect to size and sex into 2 groups. One group received the tryptophan-free diet, and the other, the diet with tryptophan.

The tryptophan-free diet contained: acid hydrolyzed casein product, 147 g.; l-cystine, 1.5 g.; sucrose, 150 g.; starch, 420 g.; agar, 20 g.; salt mixture, 20 g.; Crisco, 190 g.; Mead-Johnson's brewers' yeast, 42.7 g.; water to make to proper consistency. To prepare the diet with tryptophan, 2 g. of tryptophan were added to the amounts of ingredients given in the above diet. Viosterol was given as a vitamin D supplement. The salt mixture contained: NaCl, 18.9 g.; $CaHPO_4$, anhydrous, 25 g.; $MgSO_4$, anhydrous, 6.86 g.; $KHCO_3$, 44.4 g.; KCl, 2.88 g.; Fe citrate, 2.21 g.; $CuSO_4$, anhydrous, 0.24 g.; $MnSO_4$, anhydrous, 0.15 g.; KI, 0.015 g.; NaF, 0.03 g. This diet was used by Albanese and Buschke in their studies of the effects of tryptophan *(2)* deficiency in rats.

The rats which received the diet with tryptophan continued to grow and appeared to be in good health, while those which received the tryptophan-free diet began to lose weight and to die. After the rats had ingested the diets 25 days, all those sur-

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[1] A preliminary report of this work was given before the Division of Biological Chemistry at the Detroit meeting of the American Chemical Society, 1943.

[2] This work was supported by a grant from the Fluid Research Fund of the University of Rochester School of Medicine and Dentistry.

[3] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

viving in both groups were sacrificed, and the amount of vitamin A in their livers and lungs determined by the method previously *(3)* described.

The mean amount of vitamin A in the livers of the rats which received the diet with tryptophan was 1610 I. U. (International Units), and in the lungs, 4.33 I. U., while the corresponding values for the rats which received the tryptophan-free diet were 780 I. U., and 2.43 I. U. There was so much variation in the vitamin A analyses for the rats which received the tryptophan-free diet, that there did not seem to be any correlation between the vitamin A in the tissues, the time the rats survived or their initial weight. The results of the analyses are shown in Table 1.

TABLE 1

The Amount of Vitamin A in the Livers and Lungs of 3-4 Week-Old Rats Which Received the Diet with Tryptophan and the Tryptophan-Deficient Diet

Diet	No. of rats	Livers			Lungs		
		Mean I. U. vit. A in livers	σ	P. E.	Mean I. U. vit. A in lungs	σ	P. E.
With tryptophan	30	1610	590	70	4.33	2.20	0.27
Tryptophan-deficient	29	780	540	70	2.43	2.36	0.30

THE EFFECT OF THE TRYPTOPHAN-DEFICIENT DIET ON THE ABILITY OF RATS TO FORM ANTIBODIES AND SERUM PROTEINS

Eight 5-6-week-old rats were given the diet with tryptophan, and 7, the tryptophan-deficient diet. The vitamin A stores of these rats were controlled in the same manner as was described in the preceding experiment. After the rats had ingested the diets 2 weeks, 0.5 ml. of typhoid vaccine was injected intramuscularly. The injection was repeated 10 and 20 days later. After another interval of 8 days, the immunized animals were anesthetized with illuminating gas, the heart exposed and blood obtained by heart puncture. The pooled blood of the group which was given the diet with tryptophan had an antibody titer of 1 :160, while that of the other group had a titer of 1 :40. The blood of unimmunized control rats had no antibody titer. In Table 2 are given the results of the vitamin A analyses, which again show that the group which received the diet with tryptophan had the greater stores of vitamin A. The vitamin A stores of these rats were somewhat higher than those in the preceding experiment, probably because they were older and had ingested more of the Purina dog chow diet and also absorbed the drop of fish liver oil more completely.

TABLE 2

The Amount of Vitamin A in the Livers and Lungs of Immunized 5-6 Week-Old Rats Which Received the Diet with Tryptophan and the Tryptophan-Deficient Diet

Diet	No. of rats	Livers				Lungs			
		Mean wt. g.	Mean I. U. vit. A in liver	σ	P. E.	Mean wt. g.	Mean I. U. vit. A in lungs	σ	P. E.
With tryptophan	8	4.29	2450	240	60	0.418	5.66	2.20	0.53
Tryptophan-deficient	7	1.64	1680	210	60	0.318	1.71	0.68	0.19

The mean weight of the livers of the group which received the diet with tryptophan was 4.29 g., and of the other group, 1.64 g., which indicates how much better the growth of the rats which received the former diet was.

The experiment was repeated with groups of rats each containing 15 members. The blood of the immunized group which received the diet with tryptophan had an antibody titer of 1:2560, while that of the other group had a titer of 1:320. The blood of the unimmunized control rats had no antibody titer. Attempts to immunize rats with Pneumococcus type 1 antigen resulted in failure, for their blood showed no antibody titer.

The mean serum proteins of the rats which received the diet with tryptophan were 6.79 percent, the albumin being 4.87 percent and the globulin, 1.92 percent, while the corresponding values for the other group were 5.67 percent, 3.93 percent, and 1.74 percent.

THE EFFECT OF VITAMIN E IN THE GROWTH AND VITAMIN A STORES OF RATS WHICH RECEIVED THE DIET WITH TRYPTOPHAN

Experiment A. Twenty-seven rats, 4-5 weeks old, the vitamin A stores of which were controlled as before, were given the diet with tryptophan and 28 similar rats, the diet supplemented with 0.5 mg. vitamin E each day. Since Crisco contains some vitamin E, the diet with tryptophan provided sufficient vitamin E for normal nutrition. The vitamin E supplement was prepared by diluting 3 g. of a natural oil containing 34 percent mixed tocopherols with 77 g. of olive oil. Two drops of this solution, containing a total of 0.5 mg. vitamin E were given to the rats by mouth each day. The rats in the other group received 2 drops of olive oil each day.

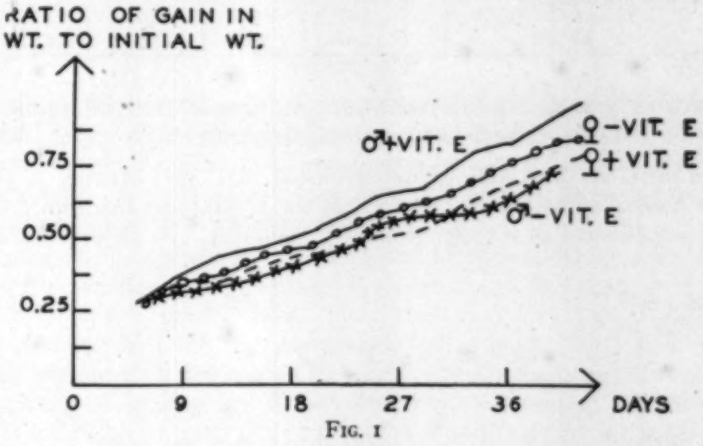

FIG. 1

The rats were weighed twice each week. The growth curves are shown in Fig. 1, the ratio of gain in weight to initial weight being plotted against time in days the rats had received the diets. The male rats which received vitamin E showed better growth than those which did not, while there was little difference in the growth of the female groups. After the rats had ingested the diets 42 days, they were sacrificed.

Experiment B. Two groups of 11-12-week-old rats, the vitamin A stores of which were controlled as before except that each rat received 2 drops of the fish liver oil, were given the diet with tryptophan. The diet of one group was supplemented with 1 mg. of vitamin E each day. After the diets had been ingested 64 days, the rats were sacrificed. The vitamin A analyses for experiments A and B are given in Table 3.

In agreement with the work of others, we found that vitamin E had a sparing action on the vitamin A stores even though the rats received no vitamin A after the diets were commenced and the older groups were almost mature. The female rats had greater stores of vitamin A than the males.

TABLE 3

The Effect of Vitamin E on the Amount of Vitamin A in the Livers and Lungs of Rats Which Received the Diet with Tryptophan

Experiment A (4-5 week-old rats)

Vit. E supplement	No. of rats	Livers			Lungs		
		Mean I. U. vit. A in livers	σ	P. E.	Mean I. U. vit. A in lungs	σ	P. E.
0.5 mg. vit. E per day	14 ♂	1150	340	60	8.09	1.94	0.34
	13 ♀	1450	170	30	6.23	1.25	0.23
None	10 ♂	930	350	80	6.76	2.09	0.49
	18 ♀	1190	320	50	7.71	5.55	0.87

Experiment B (11-12 week-old rats)

Vit. E supplement	No. of rats	Livers			Lungs		
		Mean I. U. vit. A in livers	σ	P. E.	Mean I. U. vit. A in lungs	σ	P. E.
1 mg. vit. E per day	14 ♂	2580	600	110	6.88	1.94	0.34
	16 ♀	2650	550	100	7.26	3.65	0.61
None	14 ♂	2270	300	50	6.92	2.09	0.38
	16 ♀	2520	610	100	6.42	1.71	0.30

THE EFFECT OF VITAMIN E ON THE SURVIVAL OF RATS WHICH RECEIVED THE TRYPTOPHAN-DEFICIENT DIET

In experiment A, 2 groups of 4-5-week-old rats, the vitamin A reserves of which were controlled as before, were given the tryptophan-free diet. One group received the supplement of 0.5 mg. vitamin E each day. In experiment B, the rats

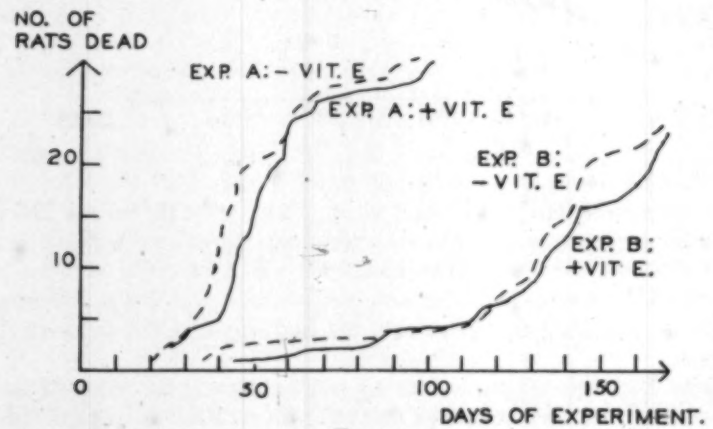

FIG. 2

were 11-12 weeks old, and one group received the supplement of 1 mg. of vitamin E each day. From a consideration of Fig. 2, it is evident that the groups as a whole

which received vitamin E survived longer than those which did not receive vitamin E. Table 4, in which the results of the vitamin A analyses and the mean time of survival of the various groups are given, indicates that the females in general survived longer than the males. Vitamin E prolonged the life of the males, but did not do so in the case of the females.

TABLE 4

The Effect of Vitamin E on the Survival and on the Vitamin A Stores of Rats Which Received the Tryptophan-Deficient Diet

Experiment A (4-5 week-old rats)

Vit. E supplement	No. of rats	Mean days rats survived	Mean I. U. vit. A in livers	Mean I. U. vit. A in lungs
0.5 mg. vit. E per day	11 ♂	51.2	500	1.71
	18 ♀	55.5	480	1.71
None	14 ♂	41.8	690	2.55
	16 ♀	53.9	650	2.28

Experiment B (11-12 week-old rats)

Vit. E supplement	No. of rats	Mean days rats survived	Mean I. U. vit. A in livers	Mean I. U. vit. A in lungs
1 mg. vit. E per day	16 ♂	152	1210	1.60
	14 ♀	133	1500	2.17
None	15 ♂	135	1190	2.36
	15 ♀	142	1580	2.74

COMMENTS

Our studies again emphasize the importance of ingesting a diet which includes proteins that contain all the essential amino acids. In rats, the diet which was deficient in one essential amino acid, tryptophan, depleted their vitamin A stores, caused a decrease in their serum proteins and reduced their capacity to form antibodies which would protect them against disease.

Our results are in agreement with those of Hickman, Kaley and Harris, who investigated the sparing action of vitamin E on vitamin A and the growth-promoting effect *(4)* of vitamin E in male rats. Since the rats which died as a result of the tryptophan-deficient diet still had considerable vitamin A reserves in their livers, the effect of vitamin E in prolonging the life of the male rats must be due to some other factor than its sparing action on vitamin A. Vitamin E therefore seems to have several functions in nutrition, and precautions should be taken to prevent its destruction in the processing of foods.

In the tryptophan-deficient rats, vitamin E did not seem to have a sparing effect on their vitamin A stores. This may be a very important point, indicating, perhaps, how vitamin E spares vitamin A in the organism.

CONCLUSIONS

The tryptophan-free diet depleted the vitamin A stores of rats, caused a decrease in their serum proteins and reduced their capacity to form antibodies when immunized with typhoid vaccine. Supplements of vitamin E increased the time of survival of male rats which received the tryptophan-deficient diet, and had a sparing action on the vitamin A stores of rats which ingested the diet with tryptophan. Vitamin E accelerated the growth of the male rats which were given the diet with tryptophan, but had little effect on the growth of the females.

ACKNOWLEDGMENTS

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AMINO ACIDS IN FOOD AND ANALYTICAL METHODS FOR THEIR DETERMINATION * [1]

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Glycine and leucine were isolated from gelatin by Braconnot *(1)* in 1820, yet nearly a century elapsed before serious attempts were made to characterize proteins by gravimetric determination of their constituent amino acids. The attention was diverted to the determination of carbon, hydrogen, and nitrogen in proteins and leading chemists, particularly Mulder in Holland and Liebig in Germany, sought to prove that all proteins contained a life-giving radical. Liebig proposed that both plant and animal proteins contained only four kinds of protein—casein, gelatin, fibrin and albumin—but by 1845 he had abandoned this hypothesis *(2)*.

Fifty years later 14 amino acids had been discovered in proteins yet, prior to 1900, no noteworthy quantitative procedure for the determination of amino acids had been described. Kjeldahl's *(3)* simplified method for the determination of nitrogen, reported in 1883, was employed by Hausmann *(4)* in 1899 for the differentiation of proteins in terms of the nitrogen distributed between the humin, the amides, the phosphotungstic acid precipitate and the phosphotungstic acid filtrate. Hausmann's method was improved and extended by Van Slyke *(5)* in 1911. Kossel and Kutscher's *(6)* silver salt procedure for the separation and quantitative determination of arginine, histidine and lysine was described in 1900 and Fischer's *(6)* ester method for the fractionation and isolation of glutamic acid, glycine, and 7 other amino acids was introduced in 1901. Although arginine, aspartic acid, glycine, histidine, hydroxyproline, phenylalanine, proline, and lysine have been determined gravimetrically as the flavianate, diflavianate, nitranilate, trioxalatochromiate, 3, 4-dichlorobenzene sulfonate, rhodanilate, reineckate, picrate, or the copper salt *(7)* few reliable data have been obtained with the aid of these derivatives during the past 45 years. It has been shown, however, that amino acids may be determined accurately by Bergmann's *(8)* solubility product method and Rittenberg and Foster's *(9)* isotope dilution procedure.

Colorimetric methods have been described for the determination of all but a few of the amino acids which are convenient, time- and material-saving and well adapted to routine analyses where only comparative data are required. It has been recognized, however, that in general the data are not highly accurate owing to the nonspecificity of the color-forming reagents. Methods for the determination of amino acids by adsorption on charcoal and other adsorbents, ion exchange with natural zeolites and synthetic resins, partition between immiscible liquids, selective oxidation, enzymatic degradation and ionophoresis have been described in recent literature *(10)* but not all of these procedures give dependable results in their present state of development.

Consideration of microbiological methods for the determination of amino acids is the primary purpose of the present discussion. Even though microbiological procedures have been developed only since 1943, Professor Chibnall of the Biochemical Laboratory, Cambridge, England, has stated in a recent personal communication that, "The microanalytical technique . . . promises to be so extraordinarily useful that I think the time is fast approaching when almost all other methods will be

* The following individuals have collaborated in the studies carried on in the speaker's laboratory: Harriette Block, Merrill N. Camien, Willi Frankl, Bruce Merrifield, Louis B. Rockland, Dr. S. Shankman and Dr. Herman F. Schott.

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

clearly outdated." That it has been possible, in such a short time, to make such marked progress should be credited, largely, to those early workers who made exhaustive studies of the growth factors required in the nutrition of bacteria. The historical development and present-day knowledge of this topic have been presented in the excellent review papers by Snell *(11)*, Peterson and Peterson *(12)*, and Knight *(13)* which appeared in 1945.

The cultivation of bacteria *in vitro* on media containing complex natural products has long been the practice of investigators interested primarily in observing the morphological and metabolic habits of microorganisms but the advantages of media of known chemical composition were recognized by Uschinsky *(14)* as early as 1893. The difficulty of this approach became apparent after the discovery by Wildiers *(15)* in 1901 and later workers that special growth factors were required for the abundant growth of bacteria, yeasts, molds, protozoa and other types of living organisms. That microorganisms might be employed for the determination of vitamins was proposed in 1919 by Williams *(16)* who suggested that yeast be used for this purpose, but it was not until 1935 that a reasonably specific method, the determination of thiamine with a mold, was described by Schopfer *(17)*. Investigations initiated by Snell and Peterson in 1936 led in 1939 to the elaboration by Snell and Strong *(18)* of a basal medium which was highly specific for the determination of riboflavin with *Lactobacillus casei*. Methods have been described subsequently for the determination of half a dozen vitamins with as many strains of lactic acid bacteria.

The first investigations of the amino acid requirements of bacteria were made by Mueller *(19)* and Fildes and Richardson *(20)* in 1935. It was reported by Mueller that one strain of diphtheria bacilli required five amino acids and another one eight amino acids while Fildes and Richardson found that *Clostridium sporogenes* required nine amino acids. The amino acid requirements of numerous strains of lactic acid bacteria were studied by Orla-Jensen *et al. (21)* in 1936. During the years, 1937 to 1940, Snell and co-workers *(22)* found that tryptophane was required by *Lactobacillus casei*, Möller *(23)* found that five amino acids were essential for *L. plantarum*, Wood *et al. (24)* reported that twelve amino acids were essential or accessory for the heterofermentative lactobacilli *L. buchneri*, *L. mannitopoeus* and *L. lycopersici* and Hutchings and Peterson *(25)* obtained nearly maximum growth of *L. casei* with a medium containing sixteen amino acids.

Lyman and co-workers *(26)* stated in 1943 that microbiological techniques similar to those employed for vitamin assays could be used for the rapid and accurate determination of amino acids, particularly isoleucine, leucine and valine. The organism recommended was *Lactobacillus arabinosus* 17-5 and the basal medium was that described by Snell and Wright *(27)* in 1941 for the determination of nicotinic acid except that the casein hydrolysate was replaced by the 17 amino acids found to be essential or stimulatory. About the same time Shankman *(28)* reported that *L. arabinosus* 17-5 required eight amino acids and Shankman, Dunn and Rubin *(29)* determined these amino acids with an average error of 3.3 per cent in a mixture containing eleven amino acids using *L. arabinosus* 17-5 and Shankman's modification of Pollack and Linder's *(30)* basal medium containing 20 amino acids.

During the past two years eighteen amino acids have been determined in protein hydrolysates with *Streptococcus faecalis (lactis R) Leuconostoc mesenteroides* P-60, *Eberthella typhosa*, mutant strains of *Escherichia coli* and *Neurospora crassa*, and the lactobacilli *arabinosus* 17-5, *casei* ε, *delbrückii* LD5 and *fermenti* 36. It may be seen from Table 1 that from three to thirteen amino acids have been determined with six lactic acid bacteria and that each of these amino acids has been determined with from one to four of these organisms. No procedure has been described for the

determination of hydroxyproline and the methods are not entirely satisfactory for some other amino acids.

In general, the pattern established for vitamin assays has been followed. Amino acid assays were first made with the homofermentative lactobacilli, *arabinosus* and *casei*, the basal media were similar to those employed for the determination of riboflavin and nicotinic acid and the techniques were analogous to those used for the assay of vitamins. Although Greene and Black *(31)* showed that tryptophane could be determined with reasonable accuracy using a basal medium containing acid-hydrolyzed casein, amino acids have been substituted for casein hydrolysate in the media used for the determination of other amino acids. It has been found that, of the twenty-one amino acids which have been included in basal media, some were essential, some stimulatory, and some non-essential. The amino acids have been classified in this manner somewhat arbitrarily although there have been attempts to determine which of the numerous variables are the most critical. Attention has been given in these studies to the concentration of the inoculum, the time and temperature of incubation, the proportions and levels of the amino acids and other nutrients, the specificity of amino acid antipodes and peptides, the activity of α-keto acids and other possible interfering substances and the method of assay.

TABLE 1

Amino Acids Determined with Lactic Acid Bacteria

Amino acid	Arabinosus	Casei	Delbrückii	Faecalis	Fermenti	Mesenteroides	Total
Alanine				X			1
Arginine	X	X		X		X	4
Aspartic acid			X			X	2
Cystine	X					X	2
Glutamic acid		X					1
Glycine						X	1
Histidine				X	X	X	3
Isoleucine	X	X		X		X	4
Leucine	X	X		X		X	4
Lysine	X			X		X	3
Methionine	X			X	X	X	4
Phenylalanine	X	X	X			X	4
Proline						X	1
Serine		X	X			X	3
Threonine	X			X	X		3
Tryptophane	X	X		X			3
Tyrosine		X					1
Valine	X	X		X		X	4
Total	10	9	3	10	3	13	

Work in the speaker's laboratory has been directed towards the elaboration of microbiological assay procedures for the quantitative determination of amino acids in proteins, foods and other materials. Although published reports have dealt with only *Leuconostoc mesenteroides* P-60, and the lactobacilli *arabinosus* 17-5, *casei* and *fermenti* 36, the twenty-five related strains listed in Table II have been investigated using the basal medium given in Table III. Abundant growth and acid production occurred with most of the organisms. The vitamin requirements were determined by measuring the acid produced by each organism grown at 35° for as long as 140 hours in thirty-two different basal media each lacking one, but not the same, vitamin. Typical response curves obtained with these organisms are shown in Figure 1. Con-

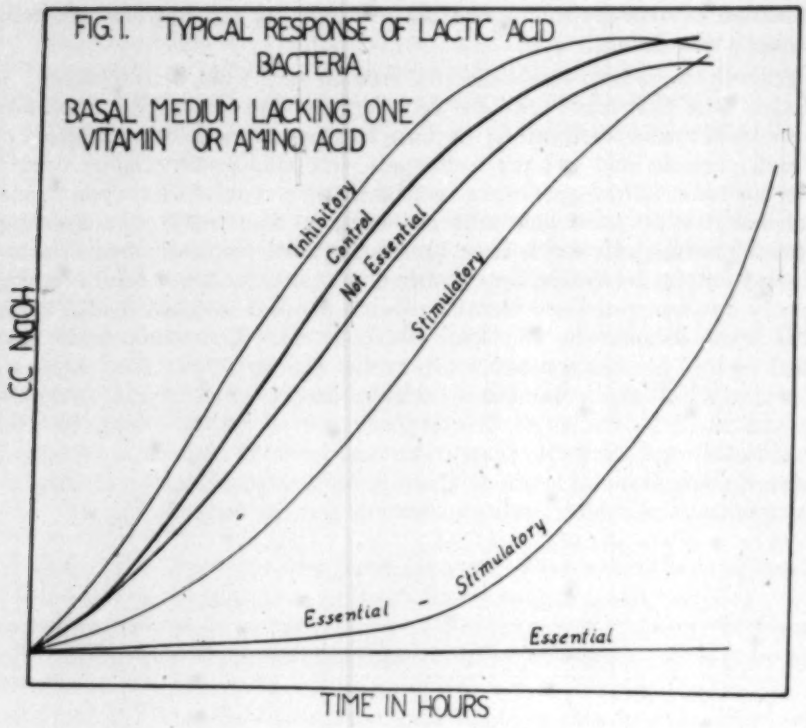


FIG. 1. TYPICAL RESPONSE OF LACTIC ACID BACTERIA
BASAL MEDIUM LACKING ONE VITAMIN OR AMINO ACID
Inhibitory
Control
Not Essential
Stimulatory
Essential - Stimulatory
Essential
CC. NaOH
TIME IN HOURS

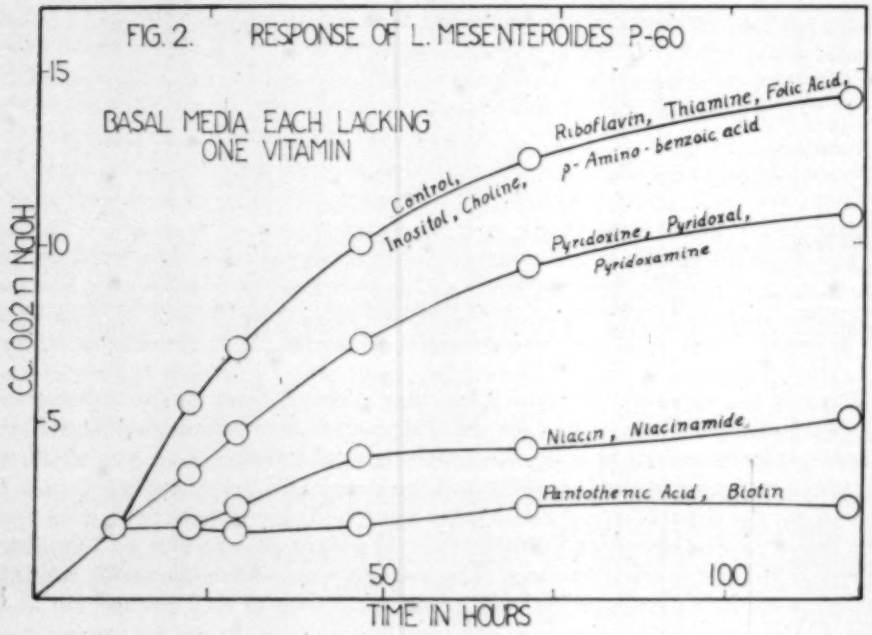
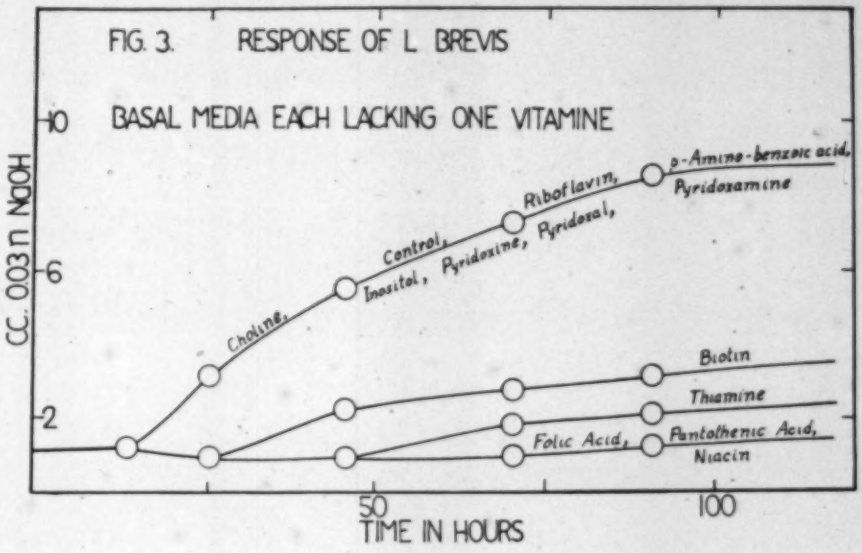


FIG. 2. RESPONSE OF L. MESENTEROIDES P-60
BASAL MEDIA EACH LACKING ONE VITAMIN
Control, Inositol, Choline,
Riboflavin, Thiamine, Folic Acid, p-Amino-benzoic acid
Pyridoxine, Pyridoxal, Pyridoxamine
Niacin, Niacinamide
Pantothenic Acid, Biotin
15
10
5
50
100
CC. 0.02 n NaOH
TIME IN HOURS

sidered in order these curves indicate respectively that the amino acid or vitamin omitted from the medium was inhibitory, nonessential, stimulatory, essential during the early hours of growth but stimulatory later, or essential. Curves signifying the vitamins in these categories with reference to *L. mesenteroides* P-60 are shown in Figure 2. It is evident that only nicotinic acid, pantothenic acid and biotin were essential for this organism. That the two additional vitamins, thiamine and folic acid, were essential for *L. brevis* may be noted from the curves shown in Figure 3. In Figure 4, it may be seen that thirteen amino acids were essential for *L. mesenteroides* P-60 and in Figure 5, that the same amino acids were required by *L. brevis*. The vitamin data obtained with twenty-one strains are summarized in Table 4 while the



amino acid data are summarized in Table 5. The amino acid sensitivity of microorganisms which have been employed for the determination of amino acids is shown in Table 6. It may be seen that, under the described experimental conditions, tryptophane has the highest and glycine the lowest sensitivity. It should be possible, therefore, to determine tryptophane with the greatest and glycine with the least accuracy with the basal media and the organisms which have been investigated up to the present time. On the whole it may be concluded that most of the amino acids may be determined with reasonable accuracy with a variety of organisms although there appears to be little hope that norleucine, hydroxyproline and norvaline can be determined with any of the strains tested. There may be reason to think, therefore, that these three amino acids may occur infrequently, if at all, in proteins.

While any amino acid may be determined microbiologically with any organisms for which it is essential, the accuracy of the assay may vary widely for different amino acids, microorganisms and environmental conditions. In general, it has been found satisfactory to inoculate the media with a suspension of washed cells diluted one to nine times with sterile saline and to incubate the tubes at 35°. The optimum time of incubation may vary from two to five days. Data of the highest accuracy are attainable only if all of the solutions are maintained during the incubation at the same, but not necessarily constant, temperature, if the sample of amino acid used as the standard is analytically pure, and if the critical measurements are made quan-

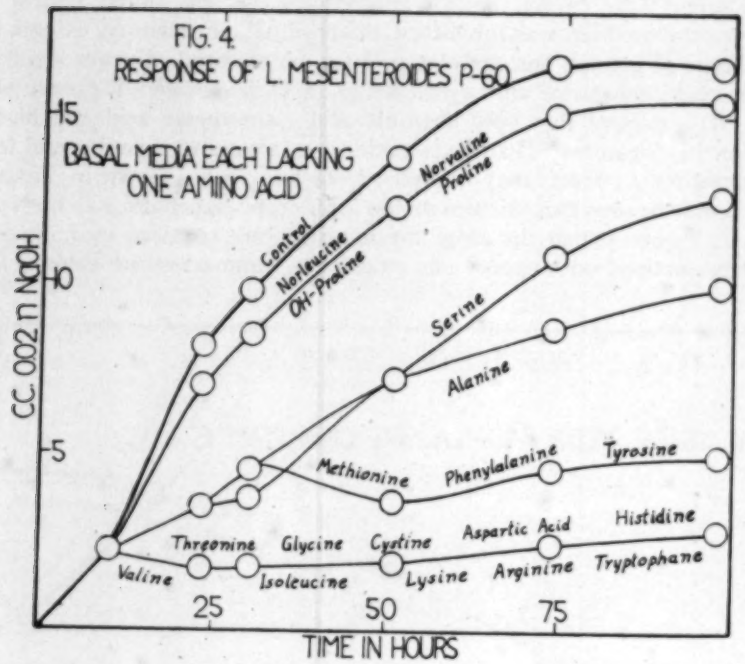


FIG. 4.
RESPONSE OF L. MESENTEROIDES P-60
BASAL MEDIA EACH LACKING ONE AMINO ACID
CC. 002 n NaOH
15
10
5
25
50
75
TIME IN HOURS
Control
Norleucine
OH-Proline
Norvaline
Proline
Serine
Alanine
Methionine
Phenylalanine
Tyrosine
Threonine
Glycine
Cystine
Aspartic Acid
Histidine
Valine
Isoleucine
Lysine
Arginine
Tryptophane

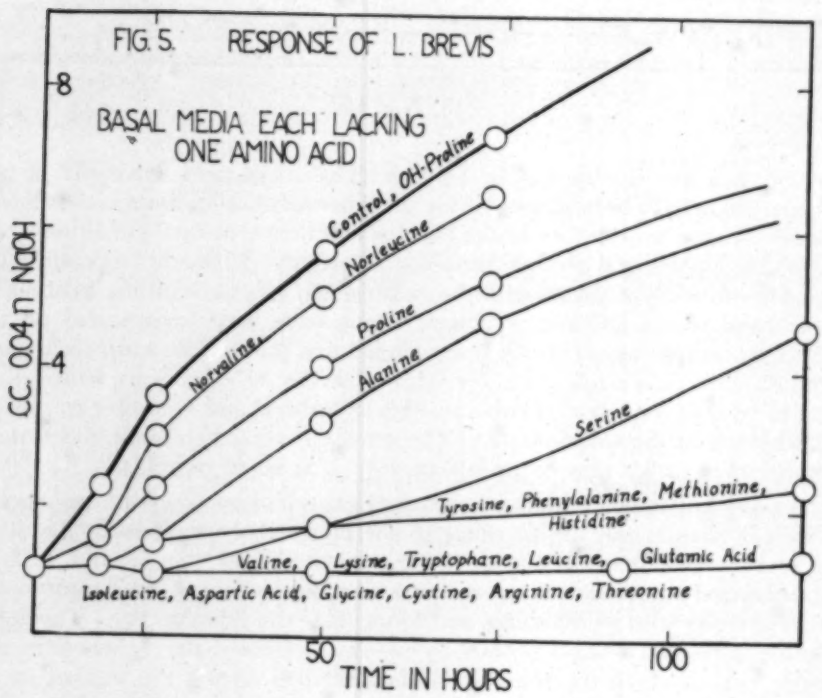


FIG. 5. RESPONSE OF L. BREVIS
BASAL MEDIA EACH LACKING ONE AMINO ACID
CC. 004 n NaOH
8
4
50
100
TIME IN HOURS
Control, OH-Proline
Norleucine
Norvaline,
Proline
Alanine
Serine
Tyrosine, Phenylalanine, Methionine, Histidine
Valine, Lysine, Tryptophane, Leucine, Glutamic Acid
Isoleucine, Aspartic Acid, Glycine, Cystine, Arginine, Threonine

TABLE 2

Lactic Acid Bacteria Tested for Amino Acid and Vitamin Requirements

Lactobacillus arabinosus 17-5	Leuconostoc citrovarum 797
Lactobacillus brassicae	Leuconostoc citrovarum 7013
Lactobacillus brevis	Leuconostoc citrovarum 8081
Lactobacillus buchneri	Leuconostoc citrovarum 8082
Lactobacillus casei	Leuconostoc dextranicum 8086
Lactobacillus delbrückii LD5	Leuconostoc dextranicum 8358
Lactobacillus fermenti 36	Leuconostoc dextranicum 8359
Lactobacillus gayonii	Leuconostoc mesenteroides P-60
Lactobacillus lycopersici	Leuconostoc mesenteroides 8293
Lactobacillus mannitopoeus	Leuconostoc mesenteroides 9135
Lactobacillus pentosus	Streptococcus faecalis (lactis R)
Lactobacillus pentoaceticus	
Lactobacillus plantarum	
Lactobacillus acidophilus	

TABLE 3

Composition of Basal Medium Used to Test Vitamin and Amino Acid Requirements of 21 Lactic Acid Bacteria

Constituent	Concentration	Constituent	Concentration
	mg./liter		mg./liter
Glucose	20 (g.)	Amino acids	
Minerals		dl-Alanine	667
Sodium acetate	12 (g.)	l(+)-Arginine·HCl	667
NH_4Cl	3 (g.)	Asparagine, natural	667
KH_2PO_4	500	l(—)-Cystine	667
K_2HPO_4	500	l(+)-Glutamic acid	667
$MgSO_4 \cdot 7H_2O$	200	Glycine	667
$FeSO_4 \cdot 6H_2O$	10	l(—)-Histidine·HCl·H_2O	667
$MnSO_4 \cdot 4H_2O$	10	l(—)-Hydroxyproline	667
NaCl	300	dl-Isoleucine	667
Purines and pyrimidine		l(—)-Leucine	667
Adenine sulfate	24	l(+)-Lysine·HCl	667
Guanine hydrochloride	24	dl-Methionine	667
Uracil	24	dl-Norleucine	667
Xanthine	24	dl-Norvaline	667
Vitamins		dl-Phenylalanine	667
Thiamine hydrochloride	1	l(—)-Proline	667
Pyridoxine	1.6	dl-Serine	667
Calcium dl-pantothenate	2	dl-Threonine	667
Riboflavin	2	l(—)-Tryptophane	667
Nicotinic acid	2	l(—)-Tyrosine	667
Biotin	5 (mcg.)	dl-Valine	667
p-Aminobenzoic acid	0.1		
Folic acid	2 (mcg.)		
Niacinamide	2		
Pyridoxal	0.10		
Pyridoxamine	0.10		

TABLE 4

Vitamin Requirements of 23 Lactic Acid Bacteria

Vitamin	Essential	Essential stimulatory	Stimulatory	Not essential	Inhibitory
Pantothenic acid	19		3	1	
Nicotinic acid	18	1	3	1	
Biotin	3	8	10	2	
Folic acid	3	7	1	12	
Pyridoxine	4	12		7	2
Riboflavin	3	7	1	12	
Thiamin	2	11	3	7	
p-Aminobenzoic acid		6		17	
Niacinamide*				10	
Inositol		2		21	
Choline		2		21	

* Tested in the presence of nicotinic acid. Only ten organisms tested.

TABLE 5

Amino Acid Requirements of 23 Lactic Acid Bacteria

Amino acid	Essential	Essential-stimulatory	Stimulatory	Non-essential	Stimulatory
Glutamic acid	23	0	0	0	0
*Valine	23	0	0	0	0
*Isoleucine	20	2	1	0	0
*Leucine	18	0	2	3	0
*Tryptophane	13	1	6	3	0
Cystine	13	1	6	3	0
*Methionine	10	9	4	0	0
*Arginine	10	4	4	4	1
*Histidine	9	2	8	4	0
*Threonine	6	6	5	5	1
*Phenylalanine	7	3	9	4	0
Tyrosine	8	3	4	8	0
Glycine	4	3	7	8	1
Aspartic acid	4	4	8	5	2
*Lysine	4	0	10	9	0
Serine	2	5	8	8	0
Alanine	3	1	9	8	2
Proline	0	0	12	11	0
Norleucine	0	0	6	17	0
Hydroxyproline	0	0	6	17	0
Norvaline	0	0	5	18	0

* Indispensable for the rat.

titatively. The most difficult problem is to determine what composition of the basal medium is most nearly optimal. Much attention has been given to the activity of indole and indole derivatives, anthranilic acid, α-keto acids, and the *d*-isomers of aspartic acid, glutamic acid, leucine and valine but these substances probably do not occur in appreciable quantities in most proteins and protein foods.

TABLE 6

Amino Acid Sensitivity of Microorganisms

Microorganism	Amino acid	Volume of base at half maximum *	Amino acid at half maximum	Sensitivity index † × 100	Reference
		ml.	γ		
L. arabinosus 17-5	Tryptophane	4.5	4.7	98	Greene and Black (1944)
L. arabinosus 17-5	Cystine	3.2	6.9	46	Dunn *et al.* (1945)
L. mesenteroides P-60	Histidine	6.6	16.5	40	Dunn *et al.* (1945)
L. fermenti 36	Methionine	2.1	9.0	22	Dunn *et al.* (1945)
L. mesenteroides P-60	Proline	6.2	28	22	Dunn *et al.* (1944)
L. mesenteroides P-60	Tyrosine	6.5	37	18	Dunn *et al.* (1944)
L. buchneri	Lysine	1.8	10	18	Wood *et al.* (1940)
S. faecalis	Threonine	5.0	38	17	Greenhut *et al.* (1946)
L. mesenteroides P-60	Leucine	6.8	42	16	Dunn *et al.* (1944)
L. arabinosus 17-5	Valine	6.5	45	14	Schweigert *et al.* (1944)
S. faecalis	Arginine	2.6	25	11	Stokes *et al.* (1945)
L. mannitopoeus	Aspartic acid	1.4	13	11	Wood *et al.* (1940)
L. delbrückii	Phenylalanine	2.3	21	11	Stokes *et al.* (1945)
L. mannitopoeus	Serine	2.0	19	10	Wood *et al.* (1940)
L. buchneri	Alanine	2	22	9	Wood *et al.* (1940)
S. faecalis	Isoleucine	2.1	30	7	Stokes *et al.* (1945)
L. arabinosus 17-5	Glutamic acid	3.6	64	5.6	Dunn *et al.* (1944)
L. mesenteroides P-60	Glycine	6.9	135	5.1	Dunn *et al.* (1944)

* Corrected for blank value.

† Equivalent to slope (ml. base/γ of amino acid at half maximum).

It has been considered of greatest importance to provide a balance of vitamins, minerals, purines, and amino acids such that the added quantities of these substances derived from the sample would not alter appreciably the response of the organism to the amino acid to be determined in the assay. Although it would be almost impossible to investigate the effect produced by all possible proportions of the approximately fifty components of the basal medium, systematic studies have been made of the concentration of each essential amino acid required for near-maximal acid production as well as the range of levels of each group of other nutrients within which acid production was constant at a particular concentration of a given essential amino acid. It has been assumed that a basal medium whose composition has been adjusted in accordance with these observations would nullify almost completely the potential influence of any substances likely to be present in the added sample. Improvements effected in the standard curve for histidine obtained with *L. mesenteroides* P-60 and medium A, shown in Figure 6, may be observed by inspection of the comparable curve, shown in Figure 7, obtained with the improved basal medium C. The curves shown in Figure 8 indicate that acid production was nearly constant at each level of methionine over a 1- to a 2.5-fold range of total amino acids. Curves indicating analogous conclusions are shown in Figure 9 for glucose and in Figure 10 for total adenine, guanine and uracil. The near-optimal levels of ammonium chloride, sodium acetate, salts A, salts B and total vitamins have been determined in comparable studies.

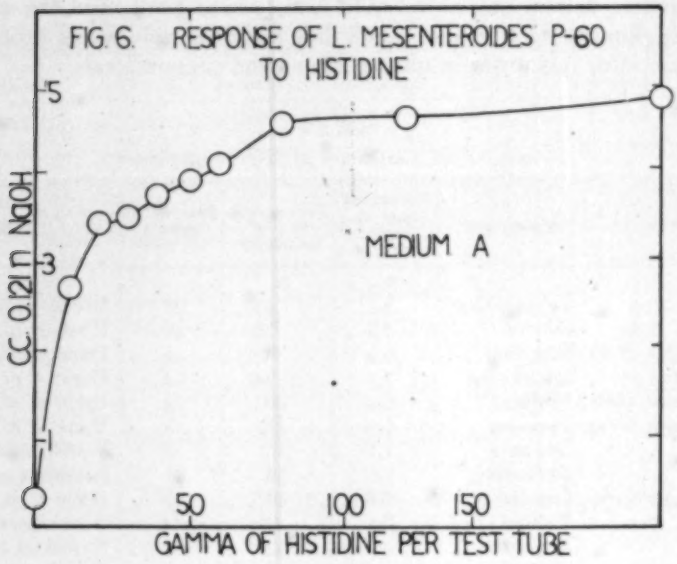


FIG. 6. RESPONSE OF L. MESENTEROIDES P-60 TO HISTIDINE
CC. 0.121 N NaOH
5
3
1
MEDIUM A
50
100
150
GAMMA OF HISTIDINE PER TEST TUBE

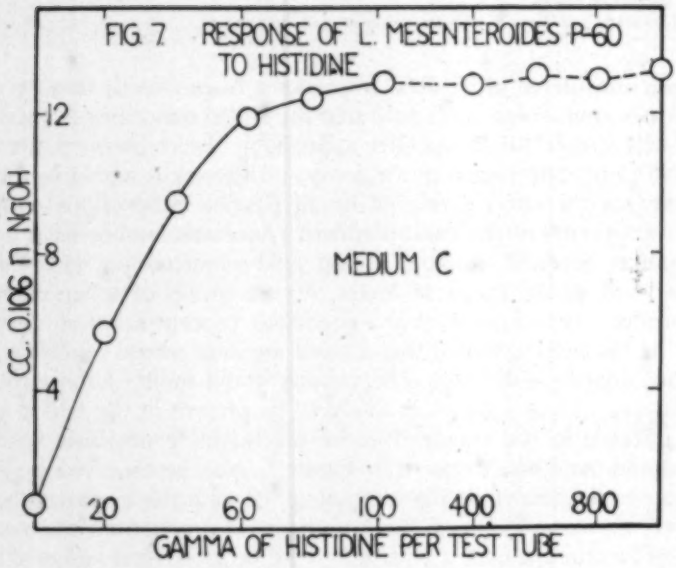
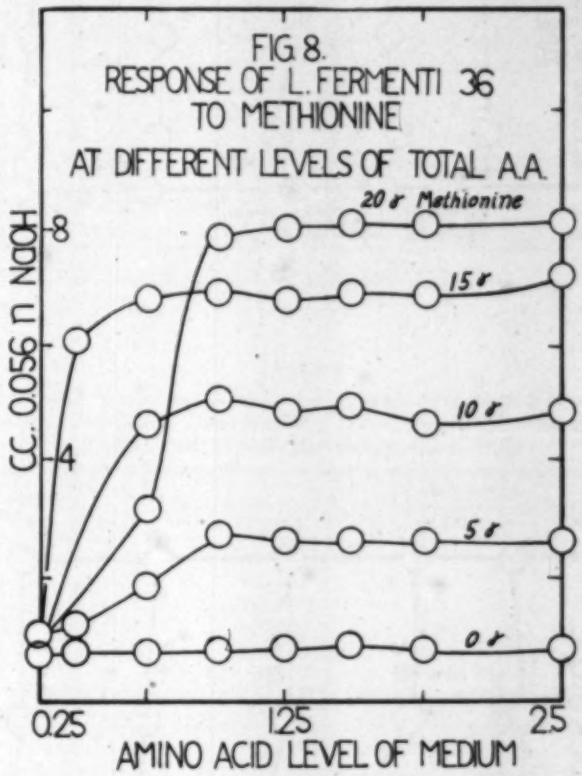


FIG. 7 RESPONSE OF L. MESENTEROIDES P-60 TO HISTIDINE
CC. 0.106 N NaOH
12
8
4
MEDIUM C
20
60
100
400
800
GAMMA OF HISTIDINE PER TEST TUBE

How accurately may an amino acid be determined by a microbiological method? Any answer to this question must give consideration to the precision attainable in assays. Some results obtained from studies of this problem are shown in the tables that follow. In Table 7 may be observed low mean deviations from the mean of the histidine values found for five replicate tubes, as well as for the range and average of the values found for the fourteen levels of histidine added to the basal medium. In Table 8, are shown values for histidine found in an amino acid test mixture simulating the composition of casein which range from 98.7 to 101.0 per cent and which average 100.2, 99.5 and 100.1 percent, respectively, at 74.96 and 120 hours of incu-



bation. In Table 9, are given uncorrected values found for histidine at five levels of casein which range from 2.66 to 2.81 per cent and which average 2.75 per cent for the tubes in one rack and 2.73 per cent for the tubes in a second rack inoculated with one half the volume of cell suspension. In Table 10 are given corrected values found for histidine in four casein preparations which range from 2.82 to 2.99 per cent and average 2.92 per cent calculated on an ash- and moisture-free basis and which range from 2.86 to 3.08 per cent and average 3.01 per cent calculated for casein containing 16.0 per cent nitrogen. The true value of histidine in casein may be about 2.95 per cent since low values would result from any carbohydrate present and from any phosphorus lost during ashing while the values calculated to 16.0 per cent nitrogen probably are slightly high. It may be concluded from these data that inappreciable amounts of histidine are destroyed during acid hydrolysis of casein even in the presence of oxygen and starch. It would appear, also, that different casein preparations contain the same proportion of α and β-casein or that α and β-casein contain

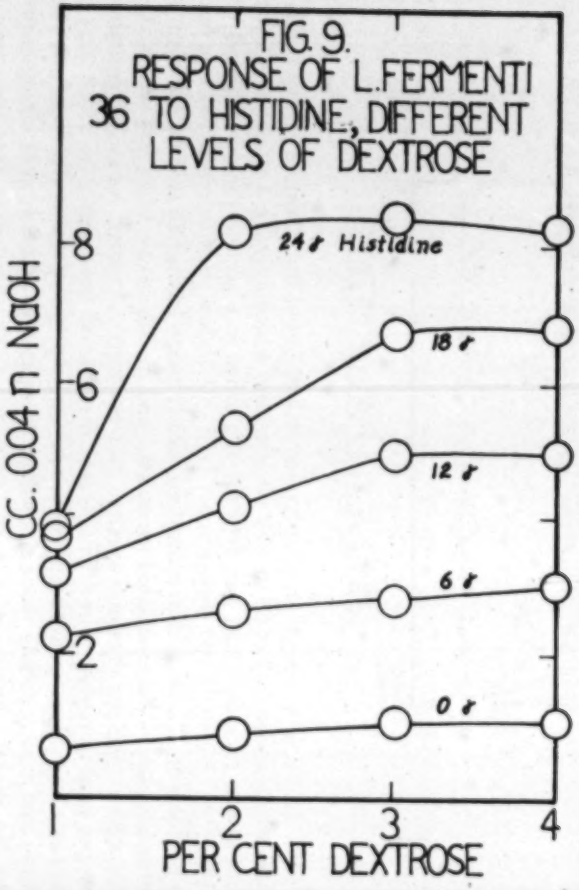


FIG. 9.
RESPONSE OF L. FERMENTI 36 TO HISTIDINE, DIFFERENT LEVELS OF DEXTROSE
CC. 0.04 n NaOH
8
6
2
24 γ Histidine
18 γ
12 γ
6 γ
0 γ
1
2
3
4
PER CENT DEXTROSE

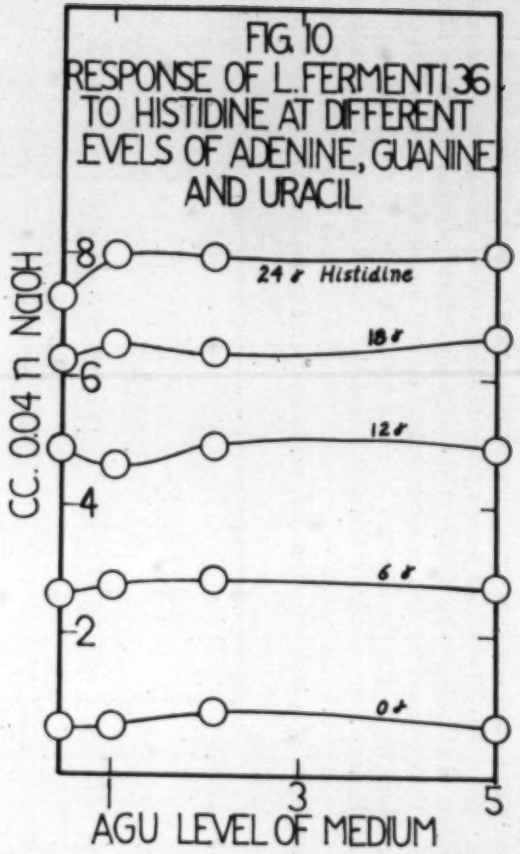


FIG. 10
RESPONSE OF L. FERMENTI 36 TO HISTIDINE AT DIFFERENT LEVELS OF ADENINE, GUANINE AND URACIL
CC. 0.04 n NaOH
8
6
4
2
24 γ Histidine
18 γ
12 γ
6 γ
0 γ
3
5
AGU LEVEL OF MEDIUM

TABLE 7

Reproducibility of Values Found for Histidine Determined with L. mesenteroides

l(—)-Histidine per tube	Volume of 0.1 O N NaOH						Mean deviation from mean
	1	2	3	4	5	Av.	
	ml.	*ml.*	*ml.*	*ml.*	*ml.*		
0.00	0.86	0.80	0.84	0.84	0.88	0.84	0.02
1.59	1.85	1.89	1.86	1.86	1.90	1.87	0.02
3.18	2.78	2.69	2.77	2.78	2.75	2.77	0.02
4.77	3.69	3.76	3.81	3.81	3.78	3.77	0.03
6.36	4.68	4.64	4.70	4.66	4.65	4.67	0.02
7.97	5.49	5.54	5.63	5.47	5.49	5.52	0.05
9.56	6.34	6.29	6.29	6.22	6.35	6.20	0.04
11.15	9.06	7.00	7.00	7.02	7.02	7.02	0.02
12.74		7.75	7.65	7.80	7.72	7.73	0.04
14.33	8.35	8.40	8.36	8.35	8.37	8.37	0.02
15.91	9.06	9.20	9.05	9.16	9.15	9.12	0.06
17.50	9.79	9.60	9.69	9.64	9.56	9.66	0.07
1909	10.16	10.24		10.15	10.17	10.18	0.03
20.68	10.83	10.79	10.74	10.72	10.77	10.77	0.05
22.27	11.22	11.33		11.24	11.29	11.27	0.04
Average							0.035

TABLE 8

Accuracy for Values Found for Histidine in Amino Acid Test Mixture Simulating Composition of Casein Determined by Electrometric Titration of Acid Produced by Leuconostoc mesenteroides P-60

l(—)-Histidine per tube	Incubation time		
	74 hrs.	96 hrs.	120 hrs.
	percent	*percent*	*percent*
4.99	100.8	100.2	100.8
9.98	101.0	98.7	100.0
14.96	100.3	99.3	99.6
19.95	100.1	100.7	99.0
24.94	98.7	100.2	101.0
Average	100.2	99.5	100.1

TABLE 9

Reproducibility of Values Found for Histidine in Casein Determined by Electrometric Titration of Acid Produced by L. mesenteroides P-60

Casein	Histidine found	
	Rack A	Rack B
	percent	*percent*
116.5	2.80	2.72
233.0	2.81	2.78
349.5	2.76	2.77
466.0	2.70	2.70
582.5	2.66	2.66
Average	2.75 ± 0.05	2.73 ± 0.04

nearly the same percentage of histidine. This evidence, and that shown in Table 11 for the close agreement of values found for threonine in an amino acid test mixture and in casein determined with three organisms and four basal media, support the view that an amino acid may be determined with high accuracy in a purified protein by microbiological methods.

TABLE 10

Percentage of Histidine in Casein

Casein source	Hydrolysis conditions *	Histidine					
		Moisture- and ash-free basis			Calc. to 16.0 percent nitrogen		
		Assay 1	Assay 2	Ave.	Assay 1	Assay 2	Ave.
		percent	*percent*	*percent*	*percent*	*percent*	*percent*
Authors	Air	2.96	2.93	2.94	3.05	3.02	3.03
Authors	Air + starch	2.91	2.95	2.93	2.99	3.04	3.02
Authors	Nitrogen	2.92	2.99	2.96	3.00	3.08	3.04
Authors	Hydrogen	2.94		2.94	3.03		3.03
SMA	Nitrogen	2.92	2.97	2.94	3.00	3.06	3.03
Commercial	Air	2.82	2.90	2.86	2.99	3.08	3.04
Vickery-Nolan	Nitrogen	2.82	2.89	2.86	2.86	2.94	2.90
Average		2.90	2.94	2.92	2.99	3.03	3.01

* Refluxed 24 hours with concentrated C.P. HCl.

TABLE 11

Threonine in Test Mixture and Casein Determined with Three Organisms and Four Basal Media

Organism	Threonine found					Basal medium
	Percent threonine in amino acid test mixture				Casein (corrected)	
	0.50	1.0	2.0	4.0		
	%	%	%	%	%	
S. faecalis	93.5	94.5	93.4	93.1	4.25	Stokes *et al.*
S. faecalis	104.0	100.5	103.5	103.5	4.36	Greenhut *et al.*
L. arabinosus 17-5	97.5	97.5	98.2	100.0	4.36	Hier *et al.*
L. fermenti 36	97.7	97.9	96.0	94.8	4.24	Dunn *et al.*
Mean	98.2	97.6	97.8	97.8	4.30	

How accurately may amino acids be determined in foods by microbiological methods? The most critical problem is concerned with the destruction of amino acids during acid hydrolysis. The data shown in Table 12 indicate that there was inappreciable destruction of nine amino acids in an amino acid mixture, simulating the composition of natural foods which had been refluxed with HCl without starch or fat and with starch and fat present in quantities from 0.01 to 4 times the amount of total amino acids. On the other hand, there was as much as 20 per cent destruction of methionine and threonine, 60 per cent of cystine, 90 per cent of tyrosine and 100 per cent of tryptophane. As shown in Table 13, the same amino acids were destroyed to about the same extent when casein was hydrolyzed under comparable conditions. That tyrosine, cystine and tryptophane are partly or wholly destroyed by acid hydrolysis of proteins has been recognized previously by other workers who have hydrolyzed proteins and foods with base or enzymes to minimize the degradation of these amino acids.

The percentages of the essential amino acids in representative foods are given in Table 14. If it is assumed that these amino acids are present in whole egg protein

TABLE 12

Values Found for Amino Acids in Test Mixtures Refluxed 24 Hours with 9 N HCl with and without Added Starch or Fat (Corn Oil)

Organism	Amino acid	Amino acid in untreated mixture		Amino acid in refluxed mixture**		
		Present	Found	Nothing added	Starch 0.04 × AA Fat 0.01 × AA	Starch 4 × AA Fat 1 × AA
		percent	*percent*	*percent*	*percent*	*percent*
L. fermenti	Histidine	1.56	100	96	93	101
	Methionine	1.58	102	98	95	83
	Threonine	1.58	96	88	80	92
L. casei	Arginine	4.35	102	100	108	93
	Tyrosine	5.26	108	112	102	12
L. arabinosus	Glutamic acid	19.0	101	97	96	100
	Isoleucine	2.37	99	98	98	104
	Leucine	8.42	95	95	100	104
	Valine	2.63	99	98	98	106
	Tryptophane	0.53	97	0.02	0.01	0.01
L. mesenteroides	Aspartic acid	7.48	89	102	103	110
	Cystine	1.58	100	68	62	39
	Glycine	5.26	102	97	95	98
	Lysine	3.37	100	99	100	105
	Phenylalanine	2.10	102	102	101	105

** Underlined values are considered to represent partial destruction of amino acids. Nearly all of the other values are within the limits of what is considered to be the probable error (about 5 percent). It is possible that some of the high and low values may have resulted from stimulation or inhibition of the organisms by degradation products of starch, fat, or both substances, but this hypothesis seems unlikely in view of the relatively low mean deviations from the mean found for the assay values at the different sample levels.

TABLE 13

Values Found for Amino Acids in Casein Samples Refluxed 24 Hours with 9 N HCl with and without Added Starch or Fat (Corn Oil)

Organism	Amino acid	Amino acid in refluxed mixture*		
		(A) Nothing added	Starch 0.04 × AA Fat 0.01 × AA	Starch 4 × AA Fat 1 × AA
		percent	*percent* of A	*percent* of A
L. fermenti	Histidine	3.10	106	94
	Methionine	2.92	100	67
	Threonine	4.10	108	90
L. casei	Arginine	3.88	103	84
	Tyrosine	6.30	75	0.4
L. arabinosus	Glutamic acid	22.2	100	99
	Isoleucine	5.74	101	99
	Leucine	8.15	95	98
	Valine	7.00	101	99
L. mesenteroides	Aspartic acid	7.18	103	100
	Cystine	0.22	91	0.1
	Lysine	7.61	103	100
	Phenylalanine	4.97	103	97

* See corresponding footnote to Table 12.

TABLE 14

Percentages of Essential Amino Acids in Representative Foods

(Calculated to 16.0 percent N)

Amino acid	Whole egg	Skim milk	Fish muscle	Soybean	Yeast purine-free	Corn germ	Whole wheat	Gelatin *	Beef muscle †	
									Found	Best
Arginine	5.7	3.0	5.8	6.9	9.0	5.6	3.3	7.6	6.0—7.1	6.0
Histidine	2.4	2.7	2.5	2.9	3.8	3.0	2.6	1.0	2.2—3.5	3.5
Isoleucine	6.7	7.5	5.8	7.0	3.8	3.8	4.1	1.7	3.4—5.3	5.3
Leucine	9.2	10.2	8.8	8.1	5.1	7.1	6.4	3.7	7.7—12.1	7.7
Lysine	7.3	8.7	8.6	7.5	9.0	5.3	2.7	4.3	7.8—8.1	7.9
Methionine	3.1	2.3	2.9	1.1	0.80	1.5	1.3	0.8	3.0—3.3	3.0
Phenylalanine	5.4	5.1	3.9	5.2	2.2	3.3	4.2	2.0	3.9—4.8	3.9
Threonine	5.3	4.6	3.4	3.3	4.1	4.5	3.3	1.5	4.4—5.4	5.4
Tryptophane	(1.6)*	1.6	1.1	(1.6)*	1.4	(0.6)*	1.0	0.0	1.2—1.3	1.3
Valine	7.1	7.4	6.7	5.6	4.8	5.3	3.6	2.5	3.4—5.2	5.2
Total	53.8	53.1	49.5	49.2	44.0	40.0	32.5	25.1	43.0—56.1	49.2

* Taken from Block and Bolling, The amino acid composition of proteins and foods, Springfield, Illinois (1945).

† Taken from Block and Bolling, Arch. Biochem., *8*, 217 (1943); Beach, *et al.*, J. Am. Diet. Assoc., *19*, 570 (1943); Schweigert, *et al.*, J. Biol. Chem., *155*, 183 (1944); Hier, *et al.*, J. Biol. Chem., *161*, 705 (1945).

in optimal proportions, it would follow that the other food proteins are deficient in at least one, and as many as nine, essential amino acids. Although the food proteins with the most amino acid deficiencies undoubtedly are of low biological value, it is difficult to make accurate comparisons of the other foods. It is generally recognized, however, that the protein requirements for nutritional and other purposes must be determined, ultimately, in terms of amino acids rather than proteins *per se*. Stare *et al. (32)* have stated recently that "improved methods of amino acid analysis may soon lead to a redefinition of protein requirement in terms of the individual amino acids and an evaluation of diets on this basis." Some estimates of amino acid requirements are shown in Table 15. Although daily allowances of essential amino

TABLE 15

Amino Acid Requirement of Man

Amino acid	Calculated on basis of amino acids				In food consumed by rats
	In average food consumed United States	To give nitrogen balance—rats (Rose's data)	Whole egg protein		
			25 percent of diet	Maintain N balance—man	
	Block [1]	Block [1]	Dunn [2]	Stare [3]	Dunn [2]
Arginine	1.2	4.7	1.4	1.8	0.7- 0.8
Histidine	2.4	2.0	0.6	0.5	0.9- 1.1
Isoleucine	3.0	3.7	1.7	1.3	1.7- 2.1
Leucine	5.4	12.5	2.3	3.6	2.3- 2.7
Lysine	6.0	5.2	1.8	1.4	1.5- 1.8
Methionine	3.7	4.1	0.8	1.9	0.7- 0.9
Phenylalanine	4.2	4.7	1.4	1.4	1.1- 1.2
Threonine	3.6	3.6	1.4	1.2	1.4- 1.7
Tryptophane	1.2	1.1	0.4	0.4	
Valine	4.2	3.2	1.8	1.3	1.9- 2.3
Total	34.9	44.9	13.6	14.8	12.2-14.6

[1] Block, R. J., Yale J. Biol. Med., *15*, 722 (1943).
[2] Dunn, *et al.*, unpublished data.
[3] Stare, F. J., *et al.*, Ann. Rev. Biochem., *14*, 431 (1945). Data taken from Block and Bolling, Amino acid composition of proteins and foods (1945).

acids considerably smaller than those calculated by Block in 1943 have been proposed recently by the other workers listed in the table, it seems probable that the requirements will be found to vary widely with the species of animal as well as with the sex, age and physiological condition of the individual.

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NICOLAS APPERT MEDAL PRESENTATION[1]

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Most of you recall the circumstances under which the Nicolas Appert Award was originated by the Chicago Section of the Institute of Food Technologists. For the benefit of those who do not, I shall briefly review them.

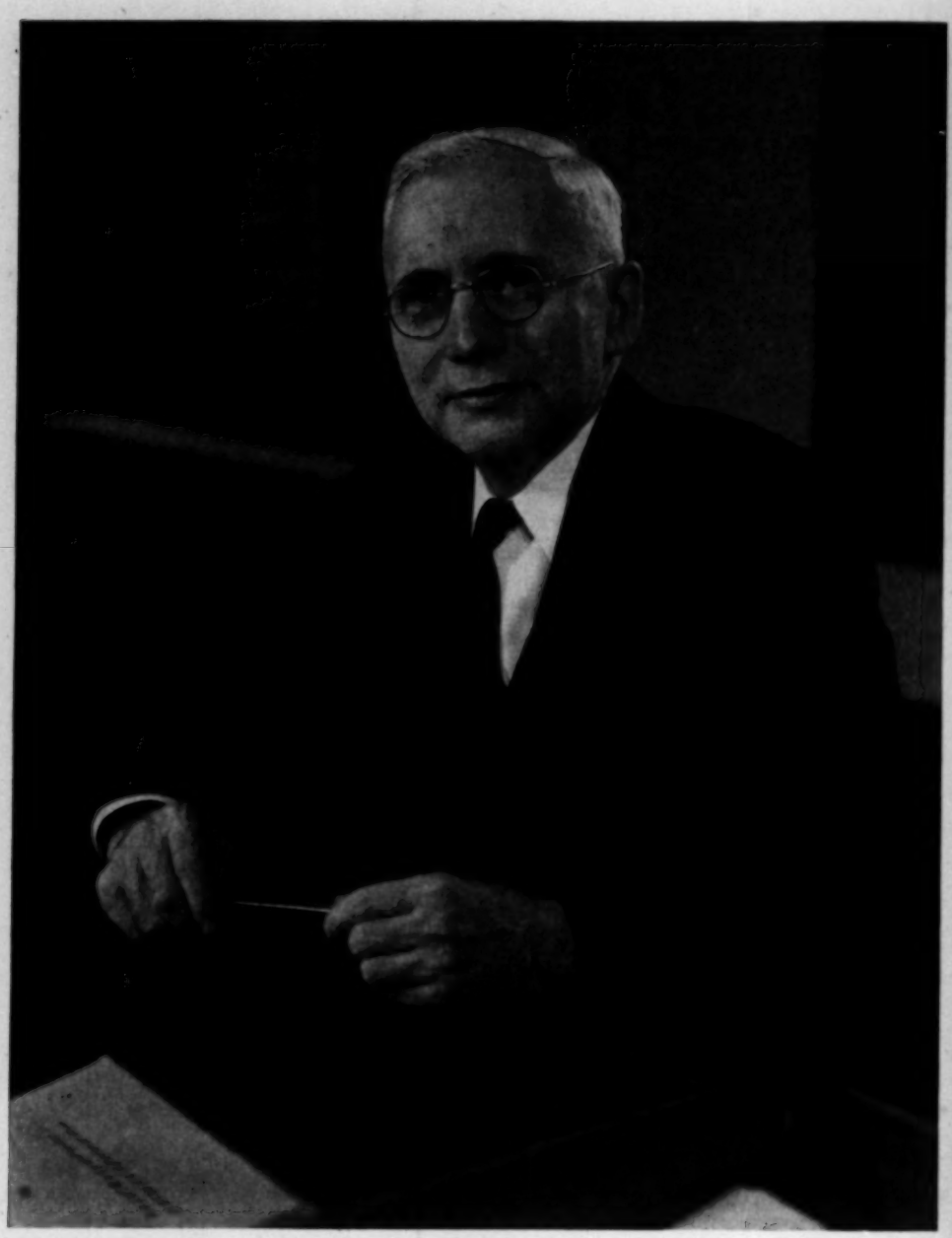
The Chicago Section is one of the largest groups in the Institute and has been active in promoting the Institute's best interests. It was for this reason that the Chicago Section established a medal award some five years ago which was to be given each year to an individual as recognition of outstanding achievement in the field of food technology. The medalist is chosen each year by a jury of nine recognized food technologists, selected as representative of various sections of the country and the several fields of food technology. The medalists elected in past years, named in the order of their election, are: Dr. William Vere Cruess, Dr. Samuel Cate Prescott, Dr. Charles Albert Browne and Dr. Avrill Wayne Bitting.

To those who are familiar with the history of the preservation of food, the name, Nicolas Appert, is particularly significant. Nicolas Appert is unquestionably the father of the food preservation industry. Some 135 years ago, he discovered and developed the fundamental principle on which our present canning industry is based. Through his labors, accurate observations, and correlation of facts gleaned from many industries, he was able to preserve food by sealing it in hermetically sealed containers and subsequently sterilizing it by heat. This is the basic principle upon which all canning is done today. It is of interest to recall that Appert's work, like much of that done in recent years, was in response to the needs of war. It is also of interest to note that the results of his work were recognized by a reward of twelve thousand francs given by the French Government and that this reward, unlike that of many others, was conferred upon him while he was still living and active. It is with this same thought that the Chicago Section selects its Nicolas Appert Medalist so that recognition of outstanding contributions to food technology may be duly recognized during the medalist's active career.

With this brief background on the Nicolas Appert Award, the selection of Dr. Clyde H. Bailey for the 1946 award seems particularly fitting. It is obviously impossible to adequately review the career of a man who has been extremely active in the field of food technology since 1905. Therefore, a few highlights of that long career must suffice.

Dr. Bailey accepted his first job as an analyst in a cereal chemistry laboratory in Minneapolis in 1905 where he remained until 1908. The following three years found him a scientific assistant at the Bureau of Plant Industry, United States Department of Agriculture at Fargo, North Dakota. Since 1911, with but few minor interruptions, he has been associated with the Department of Agriculture at the University of Minnesota of which he is now the Dean. During the time that Dr. Bailey was spending his time in research and teaching, he was a prolific writer. Papers which he has written cover work in the milling and baking industries, the chemistry of wheat flour, investigations relative to flour strength, enzymes and fermentation, special work on the study of agronomic influences on wheat, research

[1] Presented at annual banquet, Sixth Food Conference, Buffalo, N. Y., March 19, 1946.



DR. CLYDE H. BAILEY

Dean and Director of the Department of Agriculture, and Professor of Agricultural Biochemistry, University of Minnesota, St. Paul, Minnesota
Recipient of the Nicolas Appert Award in 1946

in the respiration and heating of wheat, as well as many other subjects in the general field of cereal chemistry. His two books, "Chemistry of Wheat Flour" and "Constituents of Wheat and Wheat Products," are widely recognized as authoritative in their field. Dr. Bailey's activities in the field of cereal chemistry have been further amplified by the splendid job he did as editor of *Cereal Chemistry*.

Recognition of his outstanding abilities is evidenced by the presentation to him by the Cereal Chemists' Association of their first Thomas Burr Osborne medal.

In reviewing the enormous amount of work carried out by Dr. Bailey and his associates, the characteristic which stands out, like that of Nicolas Appert, is his ability to adapt methods, procedures and apparatus of allied sciences to the problems at hand.

Perhaps a man may be judged by the work he accomplishes, but to many of us, the ability to impart and inspire others may be even more important. Besides being a scientist of the first order, Dr. Bailey is unquestionably an inspiring and able teacher. The mere fact that Dr. Bailey has served as a major advisor for approximately 50 students doing graduate work for their master's and doctor's degrees is alone a tribute to the man's capacity. When you add to that a recognized popularity among his students, you have further proof of his versatility. Evidence of his popularity is the award of the "little red oil can" presented to him by students at the University of Minnesota. The "little red oil can" is given annually by students to the faculty member most popular and who has given outstanding service. The citation to Dr. Bailey when this award was given him was as follows:

"An inspired teacher, an internationally-known cereal chemist, an advisor to graduate students from foreign lands, a leader in theoretical and industrial research, a scholar in the best meaning of the word, and a cultured student. He has been, above all, a true friend to every student, giving generously and cheerfully serious thought and valuable time from a very busy life to their personal problems."

In spite of the enormous amount of work Dr. Bailey has accomplished, he still finds time to serve on 14 University committees which vary widely in nature. In addition, he serves on 21 non-university committees, including the Hormel Institute Board, the Food Processing Committee of the Agricultural Research Administration of the United States Department of Agriculture, the Monograph Committee of the American Association of Cereal Chemists, and as Chairman of the Education and Curriculum Committee of the Institute of Food Technologists. Such diversity of activities surely can be handled only by a man who is not only a doer but an administrator. As one of his closest associates says, "Dr. Bailey is an outstanding administrator, and I never knew anyone who had quite the capacity for organizing his work."

Having reviewed in these few words the career of a man who has spent his life in that field of food technology dealing largely with our daily bread, it seems not only fitting but proper that the Nicolas Appert Award this year goes to a man who might well be termed "the staff of the staff of life." Dr. Bailey, it is, therefore, with pleasure that I, as a representative of the Chicago Section of the Institute of Food Technologists, present you the Nicolas Appert Award as testimony to your outstanding achievements in the field of food technology.

PROCESSING THE WHEAT KERNEL *

C. H. BAILEY
The University of Minnesota

Nicolas Appert Medal Award Address, Institute of Food Technologists, March 19, 1946

Wheat products have come to occupy a prominent position in the diet of occidental peoples. Two factors have contributed prominently to this end. The first is the convenience attached to the storage and handling of dry material like wheat and other cereals as contrasted with moist foods such as meat and fresh vegetables. The second factor applies to wheat products particularly, and involves the unique physical properties of doughs and pastes made from wheat flour and semolinas. These properties facilitate the conversion of such doughs and pastes into bread, cakes, macaroni, and other products which have qualities not possessed by other cereal foods.

The preservation of such optimum qualities in twentieth century wheat products has not been simple and easy. As the superior food properties of certain varieties and types of wheat came to be identified, it did not follow, invariably, that these varieties or types were always possessed of agronomic characteristics that would encourage or permit large-scale culture in an organized and sustained agriculture. Let us take Marquis wheat as an example. Itself a hybrid variety, emerging from the plant breeding program of Wm. and Sir Charles Saunders of Canada, it yielded flour having excellent physical and biochemical qualities. Marquis wheat was susceptible to the prevalent races of black stem rust, however, which disease took a terrific toll of the acreage sown to it during certain crop seasons.

Resistance to stem rust was then imparted to a new hybrid wheat, of which Marquis was one of the grandparents, by introducing genes from varieties possessed of resistance to that disease. Certain of these parent varieties, apart from Marquis, actually were of singularly low quality from the technological standpoint. This masterly attack upon the wheat breeding problem, involving the combined efforts of geneticists, plant pathologists and food technologists, resulted, for example, in a rust-resistant hybrid spring wheat variety called Thatcher, that was so useful that it was actually grown on 14,600,000 acres in the Northern Great Plains area during certain seasons.

Presently leaf rust appeared, to take considerable toll of Thatcher wheat during certain crop years, and further breeding programs are being instituted to introduce resistance to that disease as well. Again recourse is had to breeding material that is not technologically suitable alone, but from which the geneticists hope to derive genes that will impart resistance to that disease as well, and without loss or alteration of the desirable qualities of the parent strains.

Is it any wonder, then, that the food technologist has played a significant role in these modern wheat breeding programs? Or, that he, in turn, has been alert to the evolution and identification of new devices and techniques that would quantitatively measure the significant technological properties of the new varieties, and their mill products? In fact, it appears that numerous of the new devices and methods designed to measure such technological properties, that have made their appearance in recent times, have emerged from the laboratories that were primarily concerned

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with wheat breeding programs. This is not surprising either, because such laboratories not only need such improved techniques to remove empiricisms from their practices, but they also come into possession of graduated series of samples that run progressively through the entire gamut of qualities that are likely to be encountered.

This introductory discussion may appear to have wandered somewhat from the subject assigned to this paper. It has been included deliberately, however, because the inherent qualities of wheat, as derived from its parentage and as influenced by the environment in which it is grown, determined, in no small measure, the evolution of the processing to which it has been subjected, in early, and even more particularly, in recent times.

The use of wheat as human food dates back to prehistoric times. Probably it was first treated by a process of parching, to which it was well adapted because, unlike the barley which preceded it in the food of certain tribes, it can be freely threshed from the tough, fibrous glumes or chaff. Then came crude milling appliances. One of the earliest was the saddle stone of Egypt and the Levant, functioning like a mortar and pestle. This was evolved into the conical quern of the Romans, and the flat mill stones, both of which devices lent themselves to the application of mechanical power and to a continuous flow of material. This use of power, in turn, led to the appearance of an industry, in which the commercial mill took over the onerous task of producing flour for a community. Wind mills, and water wheels began to provide the power previously contributed by women of the household, or slaves, or domestic animals.

These advances were paralleled by improvements in the art of grinding, to which the Egyptians added provision for sieving or bolting out the coarse fibrous bran particles. A milling "system" was evolved, which became quite extended and involved while mill stones were still in common use. "High" grinding, which implied a more gradual comminution of the wheat kernel, and with a sifting or bolting treatment following each grinding operation, led to further refinements in the entire process.

Oliver Evans, who was born near Wilmington, Delaware, in 1755 and who was trained as an engineer, made an intensive study of the mechanics of milling. A contemporary of Nicolas Appert, but working on this side of the Atlantic, Evans made a major contribution to the engineering aspects of milling about 1790. His suggestions did much to effect the redesigning of flour mills, rendering them essentially automatic, and providing means for the transfer and flow of the several streams so that the flour mill provided a continuous process. Evans' ideas and designs were so generally adopted on both sides of the Atlantic that flour milling promptly moved far in advance of the other industries of that period. Thus the so-called industrial revolution that came a quarter century later found flour milling already established in the new and startling mechanical era.

Evans' book, "The Young Mill-Wright and Miller's Guide," published in 1795, is one of the classics in the literature of food technology. Few documents exerted a more profound effect upon the development of a major industry.

About 1832 Jakob Sulzberger, a Swiss miller, began to experiment with metal cylinders in lieu of mill stones for the gradual grinding of cereals, and particularly of wheat. Bavarian, Italian, and Hungarian mills rapidly adopted the new roller-mill; in fact, the mills at Budapest received so much publicity about the middle of the century that the relatively new milling system came to be known as the Hungarian process in many lands. From that center the process was brought to the United States in the early 80's.

The combination of the roller-mill, multiple-sieve bolter, and a special bolter-aspirator combination known as the middlings purifier resulted in a complex, gradual reduction system of flour milling. In such a modern flour milling system numerous streams of flour can be identified. Briefly stated, a flour mill can be divided into four major departments of activity.

(1) Grain cleaning and conditioning. Here an effort is made to remove dirt, weed seeds, smut spores, and other foreign material if they are present in the original grain as delivered to the miller. The cleaned wheat is then brought to the optimum temperature and moisture content, these being adjusted (a) to the properties of the wheat itself, and (b) to the milling system that is to be applied to grinding it.

(2) Break system. Here the wheat is ground between fluted or corrugated rollers upwards of five times more or less. The ground material is bolted after each break, three classes of products being fractionated thus, namely (a) coarse fragments, which are reground, until, at the close of the series, they become the equivalent of bran; (b) granular particles derived chiefly from the endosperm of the wheat kernel, known collectively as middlings or semolinas, and scheduled for further processing in the reduction system; (c) break flour, the quantity of which is kept to the minimum, but which is bolted off at this point.

(3) Reduction of primary middlings. The mixed middlings, as separated from the coarse, and the fine or flour fractions resulting from the break system are further classified or graded as to physical size and structure. Each of these graded middlings is then ground separately between smooth iron rollers and the flour thus produced, on being bolted off, is known as a middlings flour. In general, these are the choicest, most highly refined flours that are produced in the mill. The coarse residue recovered from this sifting or bolting treatment progresses to the next system which may be termed:

(4) Reduction of secondary middlings. For the purpose of this discussion, this has been considered separately from the treatment of the primary middlings because of the substantial differences in the properties of the flours that result. Secondary middlings are defined in the present connection as comprising those several granular streams resulting from the removal of flour by sifting of the ground primary middlings. They are destinctly more fibrous than the primary middlings and include a larger proportion of the pericarp or branny covering of the grain; also, in certain instances, more of the germ as well. Consequently, when they are ground, more pericarp and germ are pulverized so fine that they are included in the flour that is sifted out of the ground mixture.

A discussion of the milling process is not complete without reference to certain chemical treatments that are applied to the finished flour. Four reagents have been used most commonly. Of these, nitrogen peroxide, and organic peroxide, particularly benzoyl peroxide, exert their principal effect upon the carotinoid pigments, converting a portion of these to colorless derivatives. Since most of the wheat endosperm pigment is of the xanthophyll type, and hence is not pro-vitamin A, it follows that no significant destruction of vitamin A results from these or other bleaching treatments.

Chlorine not only bleaches the carotinoids but also increases the hydrogen ion concentration of flour, thus altering both physicochemical and biochemical properties. Nitrogen trichloride, in suitable dosages, appears to have a considerable and generally a favorable effect upon the physical properties of doughs prepared from flour so treated, in addition to simple bleaching of the carotinoids.

Now let us refer back to the numerous flour streams resulting from the grinding and bolting processes already described. With the passage of time, these streams

have been subjected to increasingly refined and meticulous study of their properties and constituents. Proximate analysis, including the determination of the percentages of protein, ether extract, fiber, ash or mineral matter, and nitrogen-free extract, has long been employed. Then the kinds of proteins, of simple glycerides and compound lipoids; of specific mineral elements and of the pigments were determined. In numerous instances an effort was made to correlate these more refined analyses with the results of baking tests and measurable physical properties. Also their relation to biochemical sequences in dough fermentation and baking are observed.

Presently a succession of physical testing devices or machines began to appear, and these were applied to measurements of the properties of doughs made from these individual streams. All of these developments and observations combined to give a more complete and adequate knowledge of the differences between these flour streams, and to suggest some of the possible reasons for the variations in their technological behavior. Moreover, this increased knowledge facilitated the selection of the streams to be combined in a finished flour grade, since the latter, if it represents a substantial fraction of the flour output of a mill, will be comprised of a mixture or blend of several flour streams.

All of these tests combine to indicate that the more refined flours possess a greater trade acceptability or carry a higher consumer preference than either long-extraction or whole grain flours and meals. Doubtless this is due largely to the fact that the former can be converted into doughs which possess physical properties conducive to the production of bread and pastries of the most acceptable properties. The differences that count the most here are essentially physical differences, and appear to stem from the contribution to these properties made by the gluten proteins. Either the gluten complex of the high grade flours is inherently a more elastic coherent matrix when hydrated, or is less unfavorably affected by other constituents, such as the lipoids, present in the complex mixture.

Still more recently the vitamin content of these flour streams, and of flour grades has been attracting considerable attention. As our knowledge of these substances and their properties advanced, more refined methods for the estimation of the quantity present came to be available. It became apparent that flour millers are the custodians of much of the vitamins of the B complex present in natural foods in this country, and this occasioned increased interest in the fate of these vitamins in the production of ordinary flour and other typical flour mill products. Quantitative studies disclosed that flours resulting from the grinding of the secondary middlings, and from the final break contain more of certain of the B vitamins, including thiamine, riboflavin, and niacin, than the flours recovered from grinding the primary middlings. It is the latter which is incorporated normally in the patent flour. Consequently, the patent grades were lower in their content of these vitamins than the first clear, second clear, and red dog flours, which are rated, technologically, as of progressively lower grade.

Or, if the miller starts with the most highly refined, primary middlings flour streams in his mill, and superimposes on them, progressively, the less highly refined, in order of technological grade and baking quality, the concentration of these three B vitamins will be increased. The rate of increase will not be uniform, however. Thus the thiamine content will increase much more rapidly, relatively, than the content of the riboflavin and niacin, as the percentage of extraction advances from 60 to 80 percent. Accordingly, if an 80 percent flour is produced, it will contain about half of the thiamine in the wheat from which it is milled, about 2/5 of the riboflavin, and only ¼ of the niacin when normal roller milling processes are

employed. On the other hand, a 60 percent extraction flour, which would be equivalent to a good grade of bakers patent flour contains only about 1/10 of the niacin and thiamine, and 2/10 of the riboflavin in the wheat from which it was milled.

The preliminary studies in this field opened up a wholly new realm of interest and possibilities. Is it conceivable that new processing treatments may be evolved that will make it possible to transfer more of these vitamins from the kernel to the refined flour? While conveniently applicable practices have not yet emerged, it must be conceded that technological and scientific investigations in this field have been restricted by the recent war, and the professional staffs concerned the world over have not yet been able to apply all the requisite skills and facilities to this end.

Recognizing that the most direct and acceptable procedure to enhance the nutritive value of flour and bread is to add to them the B vitamins which were becoming available at nominal cost, the flour and bread enrichment program was set into motion early in World War II. Thus, the bread consumers of the United States were provided with the more abundant supplies of thiamine, niacin, and riboflavin, with the least alteration of the processing industries, and of the quality of the finished product that could be imagined. In these particulars the great mass of people in this country have been well served, and nutritionally protected. The general effect was to increase the content of these vitamins in enriched patent flour somewhere upwards of 6 fold over the natural or unenriched flour of the same grade.

Where critical wheat shortages existed in other parts of the world, recourse was had to longer extraction of flour, often upwards of 82-85 percent in order to produce more bread from the limited wheat supplies. The result was a darker, brownish-hued loaf which, while edible, is, generally speaking, not as acceptable to most of the consumers as the white loaf to which they have been accustomed. Information reaching me from overseas, and observations based upon earlier experiments in mass feeding, indicate that the people of Western Europe would depart promptly and eagerly from the brown, war loaf if privileged to do so.

With the reopening of communication and transportation since the close of the war, it now becomes possible to ship food and other materials to those areas which are experiencing critical shortages. If those areas are to be provided with substantial qualities of wheat from this country, what appeared at the close of the 1945 crop season to be an abundant supply locally becomes translated into a definite shortage as measured by normal consumption demands. This raised the issue early in 1946 of how to stretch this dwindling supply. Three principal alternatives present themselves: (1) To merely reduce our white bread consumption by some form of voluntary action.

(2) To mix white flour with so-called substitutes, such as corn meal. Corn is scarce, however, and, again, technological difficulties arise in baking such mixtures.

(3) To require every miller to extend the extraction of flour from each unit of wheat that he processes. This sounds simple, but when imposed as a blanket restriction, introduced many complications that are evident only to those who are engaged in the industries that use wheat products. Time does not permit of even outlining these complications here. Suffice it to say that the population of these United States is varied, and makes use of many forms of wheat products. Semolinas, and the macaroni or other edible pastes made from them, pastries, crackers, biscuit, cookies, cereal breakfast foods, special types of bread, all have peculiar and distinctive demands for quality of wheat products not met by a simple, blanket order for more extended extraction.

War Food Order No. 144 requiring millers to extract uniformly not less than 80 percent of flour from all wheat milled has been issued and went into effect on

March 1, 1946. Consequently, the flour millers of the United States are now in their first month of operations under this order. There are several procedures that may be followed by the miller in extending the total extraction of flour to the level required by this order. Beginning with the ordinary or normal type of patent flour he will first add thereto the clear flour, derived chiefly from the poorer break flours and secondary middlings flours. Such a mixture is not uncommonly known as straight grade flour in milling parlance, and would ordinarily constitute 72-74 percent of the wheat. Thus it may be regarded as about 7 percent short of the required 80 percent extraction. An additional 3-4 percent of the wheat will be found in the so-called "red-dog" or low-grade flour. This is a relatively finely comminuted material that is ordinarily used as an animal feed, being specially suited to feeding swine. Incidentally, its disappearance from the feed bins of the corn belt farmers will be felt, and can be expected to register in terms of a reduction in pork and lard supply.

Even after superimposing the red dog on the straight grade flour, the miller is likely to be short of the required 80 percent extraction, however. He is then confronted with the issue of where to find the additional 4 percent. Certain of the streams normally included in the shorts are comprised, to a substantial degree, of wheat endosperm. In fact, some types of grey shorts are about one-half endosperm. Mechanical treatment of these streams, involving regrinding and bolting, may be expected to yield a finely divided, starchy product that can be combined with the blend of straight grade and red dog flour to yield the required 80 percent.

Depending upon the streams that are selected to this end, and to the manipulation to which they are subjected, it can be assumed that rather variable products may appear at this stage. If streams relatively rich in germ are involved, the thiamine content may rise sharply, but added difficulties in storing, and in baking such products will be presented. One may assume that the miller will prefer to avoid such streams, as far as possible, even though it means incorporating more thiamine in enriching his final product.

If the final 80 percent extraction is marketed as enriched flour, it will still be necessary to add vitamins and iron. While it is too early in this program to make quantitative estimates, indications are that nearly as much riboflavin must be added as has been used with patent flour, about two-thirds as much niacin and iron, and about half as much thiamine. This will be at a cost for enriching ingredients equivalent to approximately three-fourths of the cost of enriching patent flour.

That the resulting 80 percent extraction flour will be chemically or technologically equivalent to patent flour is not to be expected. If it were, we can assume that the millers would have been producing long extraction flour for the last half century. Moreover, the 80 percent extraction flour can be expected to vary more, from grist to grist, and mill to mill, than is normally the case. Previously the miller could set a standard for his top grade of baker's flour and then blend the appropriate streams which, when combined, would reach that standard. Now the miller must recover a minimum of 80 percent of the wheat in the grist, as flour, without much freedom of rejection of anything that can be regarded as of the fineness of flour. This inevitably makes for greater variability in the finished product. These flours can be converted into edible, and acceptable bread, however, and of better quality than that which will be available to the Europeans in the months just ahead. It will constitute a challenge to the arts and skills of the American baker and housewife; a challenge to which they will rise, I am confident.